Characterization of DoD Installation Wastewater Treatment

Noblis Center for Sustainability

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1 Purpose and Summary

Purpose

The purpose of this report is to provide the Strategic Environmental Research and Development Program (SERDP)/Environmental Security Technology Certification Program (ESTCP) with an overview characterization of the wastewater treatment (WWT) facilities located on Department of Defense (DoD) military installations. Included in the characterization are insights and analysis on the types of installations that have their wastewater treated on-site versus off-site, and correlations between installation characteristics, business models for ownership and operation of facilities, the type of treatment used, and the Military Services.

Summary

Out of 167 installations examined in this report, a little over half of them (53%) had at least one on-site WWT facility. The sets of installations with off-site and on-site WWT are compiled in Appendix C. Characteristics of the on-site WWT facilities—highest treatment level, treatment technology, business model, and capacity—are compiled in Appendix D.

As expected, the strongest predictor of whether an installation has its wastewater treated on-site or off is its distance from civilian development. Isolated installations always treated their wastewater on-site, while those in close proximity to a large metropolitan area rarely did, and those embedded in an urban area never did. There is also a strong correlation with the geographic area of an installation: installations that are medium-large or larger were significantly more likely to have on-site WWT, while installations with very small to medium-small areas more often treated their wastewater off-site. In keeping with their tendency to have larger and more remote bases, the Marines Corps and Army more frequently had on-site wastewater treatment.

The set of on-site WWT facilities analyzed consists of 101 facilities on 88 bases. (Eleven installations have more than one WWT facility.) For all on-site facilities, Noblis was able to determine with a reasonable degree of certainty the business model (owner and operator) and capacity (daily design flow). For all but 15 facilities, Noblis found the highest level of treatment being used. For the type of technology employed, Noblis focused mainly on secondary treatment, since primary treatment consists only of settling and perhaps skimming, and since the exact processes used for advanced treatment were generally not determined during this phase of the project. For those facilities found to be treating to a secondary or advanced level, Noblis determined the type of secondary technology being used for 91% of them.

Of the 101 WWT facilities in this study located on DoD installations, 14% of them were owned and operated by contractors (and by public utilities in two cases). Among the government-owned facilities, just seven were operated by other entities. Some trends were observed regarding the occurrence of alternative business models (those other than government-owned, government-operated):

- Alternative models were more common in facilities with advanced treatment.
- There were no alternative models used on installations in the vicinity of, or embedded within, an urban area.
- The most prevalent alternative business model—contractor-owned, contractor-operated—occurred far more frequently with larger-capacity facilities.
- Interestingly, the vast majority of alternative business models occurred on Army installations. Only four alternative arrangements existed among the Joint Bases and other Services combined,

and all of these were the most traditional option for on-site facilities: government-owned, contractor-operated. The Army was the only Service to have on-site facilities owned by another entity, and the only one to have entered into arrangements with public utilities.

Of the 85% of facilities in this study for which the treatment level is known, secondary treatment was the highest level used for almost two-thirds of them. Less than one in seven facilities treated only to a primary level, with four using only septic lagoons or settlement ponds that do not achieve even a primary level of treatment. On the other end of the spectrum, 15% of facilities in this group use advanced treatment. Across the Services, the Air Force and Navy seldom use advanced treatment. Otherwise, the distribution of treatment levels is fairly even across the Services, with the notable exception of the Marines Corps which in all cases treated to at least a secondary level, and used advanced treatment as often as it used secondary.

Across the data set, advanced treatment was considerably more prevalent among facilities with large and very large design flows, while a limit to only primary treatment occurred more frequently among the small and very small facilities. Another strong correlation is the much higher frequency of advanced treatment on installations with large areas. No trend with respect to area was observed for facilities limited to primary or secondary treatment.

The type of secondary treatment processes used on DoD installations mirrors that of the country as a whole, in that the predominant technologies were trickling filter and activated sludge. Combined, these accounted for three-quarters of the on-site facilities evaluated. Six other secondary processes were represented, with oxidation ponds and oxidation ditches being the next most common technologies. Given the relative isolation of many DoD installations, and the large amount of land many of them occupy, one quarter of them relied solely on ponds or lagoons for treatment. These served to provide all levels of treatment, from pre-treatment through advanced, although most were primary or secondary. Most ponds or lagoons occurred on installations separated from urban development, either quite removed from any development, in a periurban area separated from any community, or near only a small town; just one was in the vicinity of a smaller city.

Surprisingly, all the Military Services differed considerably with regard to their primary and secondary treatment technology profiles. For example, the Army strongly favored trickling filters while the Navy used none; the Air Force had an unusual reliance of ponds and lagoons (37% of facilities). The Navy and Marines Corps relied on less common technologies for one-quarter of their facilities, while the Army used none of these. Factors such as installation siting and year of construction might have some bearing on these trends, but some of the difference is likely due simply to different traditions within each Service.

Some parallels were observed between the size of a WWT facility, in terms of its design capacity, and the type of technology used. The two dominant technologies—trickling filters and activated sludge—are represented across all size categories, but they do occupy somewhat different niches on DoD installations. Activated sludge was quite common among small and very small facilities, but was used in large or very large facilities only twice. Trickling filters skew the other direction, favored more by facilities with large capacities, with very few medium-small to very small facilities using this process. The preference for activated sludge in lower flow facilities may be due to its lower initial capital costs compared to trickling filter technology. Oxidation ditches were used twice as often in facilities ranging from very small to medium than they were in medium-large and large facilities, consistent with their large footprints and long retention times. Ponds and lagoons occurred across the spectrum of facility

capacities, showing little correlation with size.

The data also reveals correlations between the type of treatment technology and the population density of installations. As expected, ponds and lagoons serving as the sole treatment for domestic wastewater were absent on installations with high or very high density, as were oxidation ditches, consistent with the relatively large areas required by these approaches. Where ponds and lagoons did occur, their frequency dropped sharply with increasing density. Given a choice between trickling filters and activated sludge, trickling filters were more frequent on less dense installations, while activated sludge skewed to higher density installations.

Focusing specifically on secondary treatment technologies, the data reveal a clear correlation with an installation's proximity to development. The prevalence of the four most common technologies used by DoD installations correlates with the relative extent of their isolation, in the following order from left to right:

Pond or Lagoon **>** Oxidation Ditch **>** Trickling Filter **>** Activated Sludge.

That is, ponds and lagoons are most common is more isolated areas, while activated sludge is the most prevalent secondary technology in more urban settings. The greater representation of activated sludge in urban areas and on installations with greater density is due to its relatively compact size for the quality of effluent it yields.

2 Introduction to Wastewater Treatment Practices

This brief introduction of wastewater treatment processes, and the technologies used in them, provides the background needed for discussing the various approaches to WWT used by DoD installations.

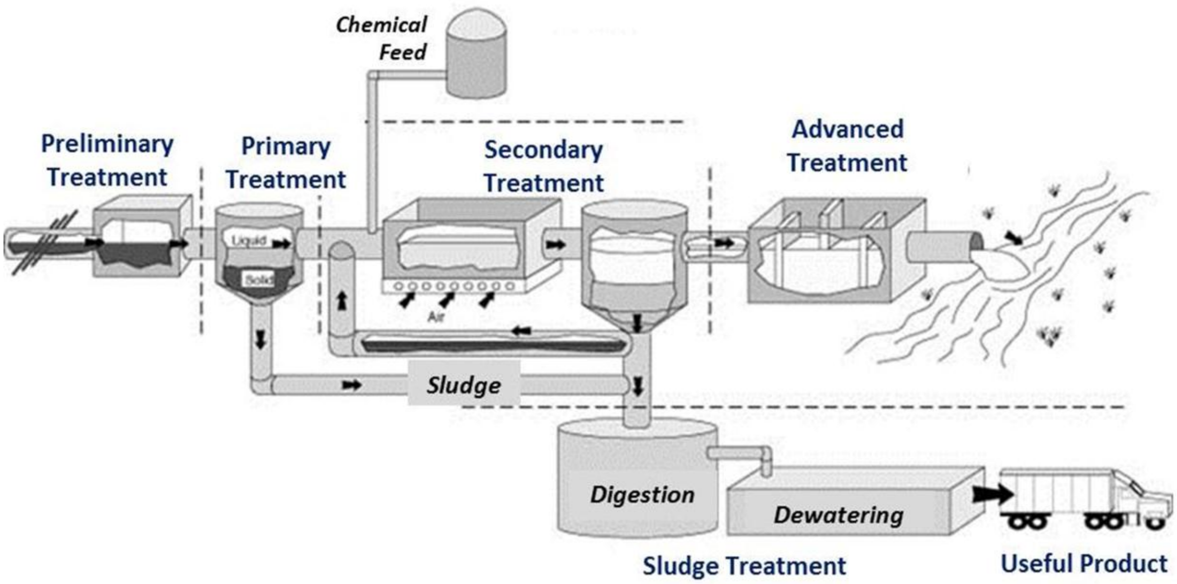

Figure 1. Schematic of General Wastewater Treatment Process

2.1 Process

A schematic of the entire process from preliminary through advanced treatment is shown in Figure 1, and an aerial photograph of a facility using oxidation ditch technology following by tertiary filtration is shown in Figure 2. Local regulations can vary, but the U.S. Environmental Protection Agency defines the different levels of treatment in terms of the concentration of biochemical oxygen demand (BOD) and total suspended solids (TSS) in the effluent, as compiled in Table 1.[1] BOD is a measure of how much oxygen bacteria consume in a given volume of water over a given period of time, making it a useful proxy for the organic content present in water. The measurement is usually given in terms of BOD_5, where the measurement is made at a temperature of 20°C after five days in the dark, but BOD_{30} (the 30-day average) is sometimes used.

Table 1. EPA Definitions of Wastewater Treatment Levels

Treatment Level	Effluent Quality (mg/L)	
	BOD_5	TSS
Primary[a]	>45	*not specified*
Secondary	≤30	≤30
Advanced	≤20	*not specified*

[a]Or >30 BOD_{30}. Primary also assumes that screening and sedimentation have occurred.

[1] EPA Clean Watersheds Needs Survey Data Dictionary, 2008, http://water.epa.gov/scitech/datait/databases/cwns/CWNS-2008-Data-Dictionary.cfm.

2.1.1 Pre-Treatment

The purpose of the pre-treatment and primary treatment stages is to separate most of the solids from the liquid component of the waste stream. Coarse solids, and most inorganic material, are removed from the waste stream during the pre-treatment process. After screening out large debris, the wastewater goes into one or more grit chambers designed to allow inorganic materials such as gravel,

1 – Headworks Building
2 – Flow Equalization Basin
3 – Oxidation Ditches & Secondary Clarifiers
4 – Tertiary Filtration & UV Disinfection
5 – Parshall Flume
6 – Old Chlorine Contact Chamber
7 – Outfall 001
8 – Aerobic Digesters
9 – Sludge Dewatering Building
10 – Sludge Drying Beds

Figure 2. Aerial View of the Wastewater Treatment Facility at Fort Carson
(Source: U.S. Army Statement of Basis for the 2010/2011 Renewal of Permit CO-0021181 for Fort Carson)

sand, and eggshells, along with abrasive organic particles such as coffee grounds, to fall out of suspension.

2.1.2 Primary Treatment

Primary treatment is the principal means of separating solids in the waste stream from the liquid. It reduces solids by approximately 70% and removes about half of the organic load. Primary treatment is based on the density of the suspended particles: particles dense enough to settle during the allotted detention time do so, forming sludge, while fats, oils, and grease float to the top and are skimmed off. Smaller particles remain suspended (comprising the TSS) and require secondary treatment to be removed. Where mechanical equipment is used, primary treatment technology essentially consists of settling tanks and skimmers. Otherwise, it simply takes the form of stabilization ponds. (Septic tanks also constitute primary treatment but on a small scale.)

2.1.3 Secondary Treatment

The secondary phase of WWT is primarily for the removal of organic matter (measured as BOD) by biological means, although it also further removes solids and reduces pathogens. Secondary treatment technologies reduce organic matter in wastewater by subjecting it to bacterial decomposition (often termed "digestion") under aerobic conditions. The rate at which organic matter is consumed depends on the rate at which dissolved oxygen can be provided to the bacteria. Therefore, there are three broad categories of secondary treatment, depending on the extent to which mechanized technologies are used to hasten the rate of oxygen transfer:

1) Non-mechanized lagoons (aerobic, facultative, or an integration of both) and passive constructed wetlands that do not have mechanical aeration or other power requirements;
2) Aerated lagoons and constructed wetlands (that is, systems augmented with mechanical aeration); and
3) High-rate aerobic treatment systems.

The high-rate systems are further broken down depending on whether the micro-organisms are suspended in the wastewater and/or attached. Common secondary treatment technologies include:

a) Fixed (Attached) Growth Systems
   - Trickling Filters
   - Rotating Biological Contactors
   - Bed Reactors (packed, fluidized, moving)
b) Suspended Growth Systems
   - Activated sludge
   - Oxidation ditch
   - Vertical loop reactor
   - Sequential batch reactor
   - Membrane Bioreactors (which treat to tertiary levels as well as secondary)
c) Mixed (Integrated) Fixed/Suspended Activated Sludge Systems

2.1.4 Advanced (Tertiary) Treatment

The primary purpose of advanced treatment is nutrient removal, phosphorus as well as further nitrogen removal. Metals and other contaminants can also be removed at this stage. The usual forms of advanced treatment are one or more of the following biological, physical or chemical treatments:

1) biological – further biological nitrogen removal;
2) physical – tertiary filtration to further reduce suspended solids (that contain nitrogen); and
3) chemical – a variety of chemical treatments, including absorption, precipitation, coagulation and/or gas stripping, to remove phosphorus and perhaps metals, as well as further reducing nitrogen.

Final disinfection and decontamination are sometimes defined as advanced treatment, but for purposes of this study these treatments are considered to be a separate process. In cases where treated wastewater is discharged or reclaimed, disinfection to remove pathogens—for example through chlorination or ultraviolet radiation—always follows the final stage of treatment, whether it be primary, secondary or advanced. Also, for purposes of this study, the removal of *dissolved* material, using reverse osmosis for example, is considered to be separate from advanced treatment.

2.2 Technologies

This introductory discussion of technologies is limited to a brief overview of the technologies Noblis found to be used by WWT plants on DoD military installations, and some related processes. The discussion covers:

Attached Growth Systems:

- Trickling filter
- Rotating biological contactor
- Sand filter

Suspended Growth Systems:

- Stabilization Ponds
- Mechanically aerated lagoons
- Activated sludge
- Oxidation ditch
- Vertical Loop Reactor
- Sequencing batch reactor

2.2.1 Stabilization Pond

A stabilization pond is a shallow body of water, surrounded by a berm, used for the primary treatment of raw sewage. It is either located in an area with impervious or nearly impervious soil, or it is lined. Lacking any mechanized aeration, it provides two treatment services: the settling of solids and the removal of some nitrogen. The quality of the effluent is strongly dependent on temperature. Colder temperatures are more effective at settling solids but ineffective at removing nitrogen, while the warmest months remove much of the BOD_5 but little of the solids. Stabilization ponds can be part of a treatment process or constitute the entire treatment. They are generally designed to handle loads of 50 pounds of BOD_5 per acre per day (corresponding to about 400 people), with detention times on the order of 45 days or more.

Not counting entirely anaerobic ponds, which are not commonly used, there are two basic types of wastewater stabilization ponds or lagoons: aerobic and facultative. In addition, there are two other types of ponds or lagoons that rely on the same processes but provide secondary and tertiary treatment:

- Oxidation Pond – receives flows from either primary treatment tanks or a stabilization pond and provides secondary treatment.
- Polishing Pond – receives flows from either an oxidation pond or other secondary treatment process and provides tertiary treatment.

All of these rely on sun, wind, and algae to support aerobic digestion. Algae are critical to the process: photosynthesis by the algae produces oxygen used by the aerobic microorganisms, which in turn produce carbon dioxide and inorganic forms of nitrogen and phosphorous used by the algae.

The advantages of ponds are they cost little to build, are long-lived, and require little energy, cost or effort to operate and maintain on a day-to-day basis. They can handle large flows and adapt readily to changes in flow, and they generate between two and five times less sludge per pound of BOD removed than conventional plants. Finally, they provide habitat for wildlife. On the other hand, the pond systems have significant disadvantages: large land requirements, the possibility of odor and groundwater contamination, high suspended solids in the effluent due to the presence of algae, a pronounced dependence of performance on ambient temperature, and the costly need every five to ten years for sludge removal.

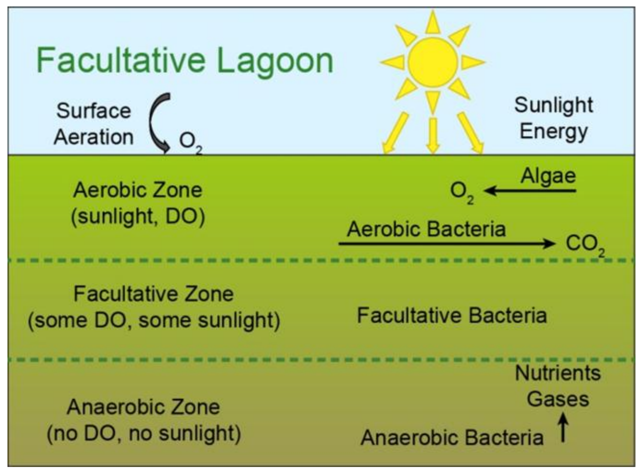

Figure 3. Schematic Drawing of a Facultative Lagoon *(Water Environment Research Foundation)*

Aerobic Lagoon

An aerobic pond or lagoon is shallow enough (about two feet, and no more than three) that oxygen is present throughout, enabling all decomposition to be aerobic. Aerobic ponds are not suitable in climates cold enough to freeze over the surface.

Facultative Lagoon

Facultative lagoons are the type most commonly used for municipal wastewater. They consist of an aerobic portion on top, an anaerobic layer on the bottom, and a "facultative" zone in between that has both aerobic and anaerobic conditions (Figure 3). Therefore facultative lagoons are about twice as deep as aerobic lagoons, or a little more. Most of the organic matter is degraded in the aerobic layer (the top two feet or so). The spent cells of microorganisms, along with a portion of organics that settle before they can be broken down, settle to the bottom in the anaerobic zone, where anaerobic processes slowly continue the decomposition. Facultative lagoons have two inherent advantages: (1) the foul-smelling compounds formed in the anaerobic zone are usually degraded in the aerobic zone; and (2) the presence of three zones with different oxygen conditions kills microorganisms not adapted to the environment, including pathogens.

Oxidation Pond

An oxidation pond is essentially the same as a stabilization pond but the influent it receives has already been subjected to primary treatment. It provides a secondary level of treatment in the form of additional settling and nitrogen removal, and some removal of fecal coliform.

Polishing Pond

A polishing, or finishing, pond is the last step between the oxidation pond (or other form of secondary treatment) and discharge to the environment. Further removal of suspended solids, nitrogen and fecal coliform occur, and much of the remaining algae can be removed by stocking the pond with algae-eating fish. Detention times are only one to three days, and the ponds are about twice as deep as stabilization and oxidation ponds to deter the growth of algae.

Figure 4. Mechanically Aerated Lagoon
(Photo: Wikipedia Commons)

2.2.2 Mechanically Aerated Lagoon

An aerated lagoon (Figure 4) is essentially an activated sludge process contained in a lagoon instead of a conventional WWT plant. Since the wastewater is mechanically aerated, the ponds can be much deeper than ponds or lagoons without mechanical aeration, roughly 15 to 25 feet, and with smaller areas. Retention times are between one and four days. Although properly designed and operated aerated lagoons can reportedly yield effluent with BOD_5 and TSS levels of 30 milligrams per liter (mg/L)—the maximum allowed under EPA's definition of secondary treatment—the effluent is generally inferior to that provided by more technically sophisticated facilities, especially in terms of suspended solids. Therefore, the effluent from an aerated lagoon is typically sent to a non-aerated lagoon for settling.

Figure 5. Trickling Filter
(Photo: Brian Hayes, "Infrastructure: A Field Guide to the Industrial Landscape")

2.2.3 Trickling Filter

A trickling filter system is an aerobic, fixed-film treatment process in which wastewater is sprayed across a bed of highly permeable media from above, trickling down over the media surface (Figure 5). The media has a gelatinous coating of microorganisms (bacteria, protozoa, and other organisms), that degrade the organic matter in the wastewater as it flows over the surface. (There is no actual filtering taking place.) Media can be natural or synthetic durable material, including rock or molded plastic. Air flowing through the open spaces keeps conditions aerobic, and the organic matter in the wastewater provides the nutrition to sustain microbial growth, e.g., the "slime" layer. Since one pass is not sufficient to decompose all the organic matter, and since dead or excess microorganisms continually slough off the slime film, the effluent is recirculated.

Figure 6. Activated Sludge Tank
(Photo: Judith Barry)

2.2.4 Activated Sludge

The term "activated sludge" refers to suspended pieces of material (or floc), each of which consists of both organic matter from wastewater and the microorganisms consuming it. The activated sludge suspended in the effluent from primary treatment is called "mixed liquor". It must be continually aerated to provide the oxygen for decomposition, and agitated to keep the floc in suspension so it remains in contact with the wastewater (Figure 6). Once treatment in the aeration basins is complete, the effluent is sent to the secondary clarifier, consisting of one or more clarification tanks, or settling basis where the activated sludge is separated from the wastewater. At this point, a portion of the activated sludge (roughly a quarter) is collected and returned to the aeration basins. This reuse of activated sludge occurs repeatedly in order to maintain a viable population of bacteria. The remaining sludge is removed, treated, and either used or disposed.

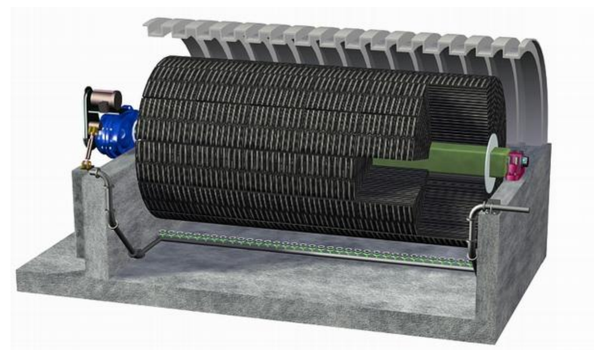

Figure 7. Schematic of Rotating Biological Contactor *(Siemens AG)*

2.2.5 Rotating Biological Contactor

A rotating biological contactor consists of a drum containing a series of circular disks that slowly rotate through wastewater (Figure 7), with the discs submerged about one-third to one-half of the way at any given time. The microorganisms grow as a biofilm attached to the rotating disks. Excess accumulation of microorganisms is sheared off by the rotation. The advantages are mechanical stability and low maintenance due to the simplicity of the system, and low energy requirements due to the slow speed of the discs. This same simplicity is its main disadvantage, as there is essentially no flexibility to alter the system.

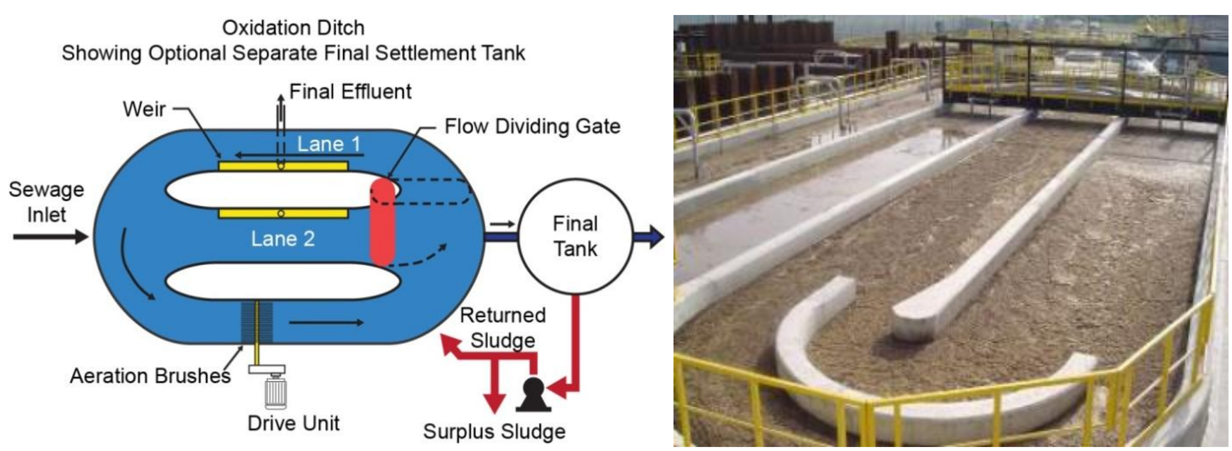

Figure 8. Oxidation Ditch
(Left: adapted from Staffordshire University; right: Lake Hughes Community Wastewater Treatment Facility)

2.2.6 Oxidation Ditch

Oxidation ditches are a modified form of activated sludge technology, based on rapidly flowing and churned wastewater moving through an endless, shallow channel (ditch) arranged in a racetrack configuration (see Figure 8). They are a favored technology in small- to medium-sized communities but with their large footprints and long retention times are unsuitable for larger populations with larger

flows. If desired, the raw sewage can flow directly into the ditch, passing only through screens rather than a primary settling tank. After its time in the ditch, the effluent goes to a clarifier to settle out the sludge, which is returned to the ditch while the clear effluent is discharged. The technology is effective at removing phosphorous as well as nitrogen, and can do so on unusually concentrated influent. The design does have operational disadvantages: it produces considerably more sludge than other methods and the wastewater has a propensity for foaming and forming scum.

2.2.7 Vertical Loop Reactor

A variation on the oxidation ditch is the vertical loop reactor, in which the flow circulates in a vertical plane rather than horizontal (Figure 9). As a result the basins are very deep and the footprint much smaller than an oxidation ditch. Also, construction costs are lower because the tanks share common walls.

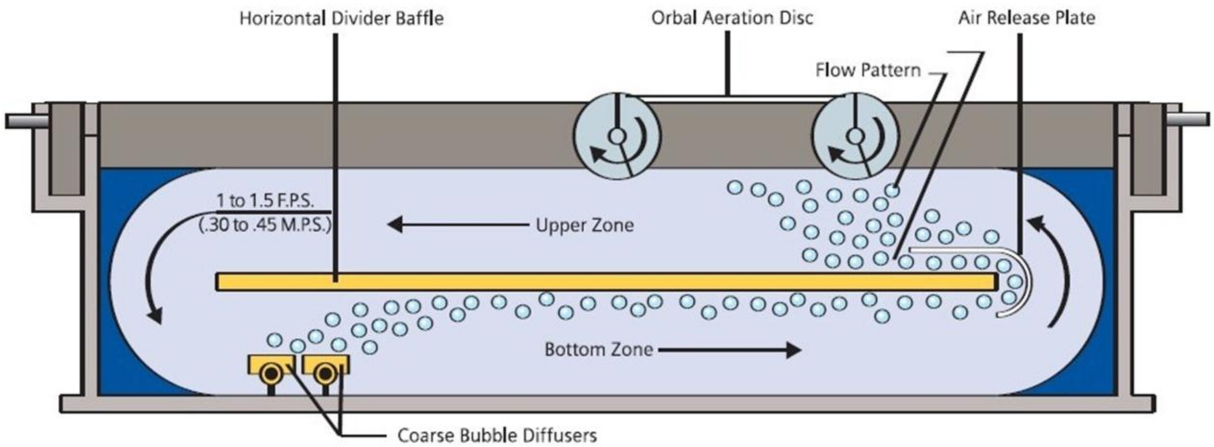

Figure 9. Schematic of a Vertical Loop Reactor
(Siemens AG)

2.2.8 Sequencing Batch Reactor

The sequencing batch reactor is a modified activated sludge process based on a repeated series of five steps, as shown in Figure 10:

- Fill – wastewater flows into the tank
- React – aerobic biological decomposition of organic matter
- Settle – the clarification step to give some of the solids time to settle out
- Draw – effluent is removed
- Idle – sludge is removed

The system consists of at least two tanks (three are shown in Figure 10), with one settling while the other is filling and aerating. Each tank typically goes through about five cycles per day. An advantage of sequencing batch reactors is they do not require a separate clarifying tank, so their footprint is smaller than a conventional system. The potential disadvantage of the process is that it requires precise computer automation to control the steps.

2.2.9 Sand Filters

Sand filtration is a fixed-growth treatment process in which the wastewater is dosed onto a bed of sand or silica particles of uniform size, with the surfaces of the grains providing substrates for the microorganisms, and the voids in between providing space for oxygenation. The treatment provided is considered advanced secondary or—if it follows secondary treatment—tertiary filtration. The system shown in Figure 11 is a continuous, upflow, deep-bed, gravity-flow sand filter, the type used for municipal-scale wastewater treatment.

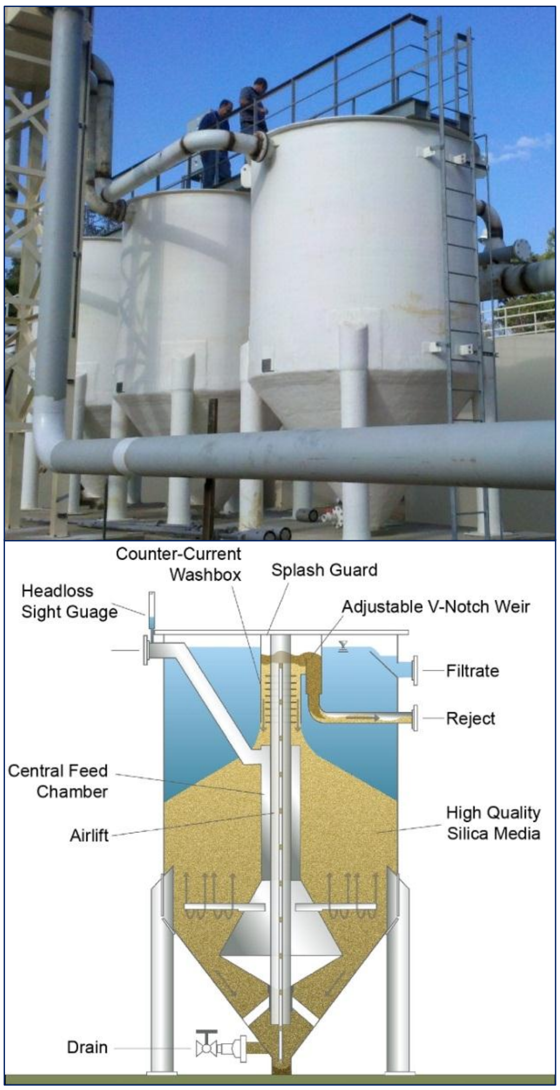

Figure 11. Sand Filtration
(Photo and schematic from Headworks® Inc.)

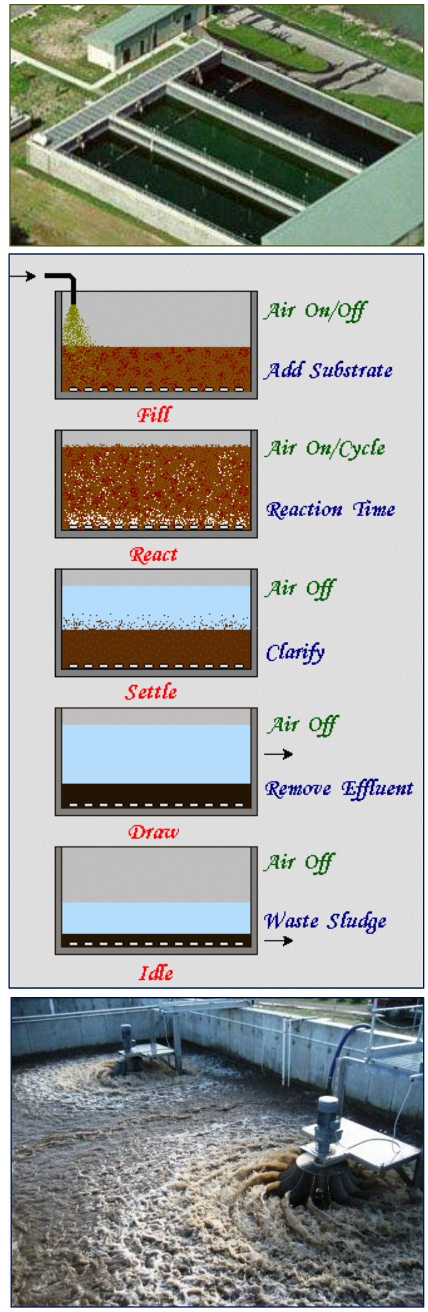

Figure 10. Sequencing Batch Reactor
Top: a 3-tank system *(credit: Siemens)*; middle: the 5-step process (*credit: Dokuz Eylül University*); bottom: aeration step (*credit: AIM Water*)

3. Characterization of DoD Installation Wastewater Treatment

3.1 Methods

3.1.1 Types of Installations Included in Study

The installations included in this study numbered 167,[2] based on restrictions to the following types:

- Naval Submarine Bases
- Naval Air Weapons Stations
- Naval Support Activities (some, depending on the mission)
- Naval Stations
- Naval Bases
- Naval Air Stations
- Naval Weapons Stations
- Air Force Bases
- Marine Corps Air Stations
- Marines Corps Air-Ground Combat Center
- Marine Corps Logistics Bases
- Marine Corps Bases
- Army Forts
- Army Proving Grounds
- Army Depots, arsenals, and ammunition plants

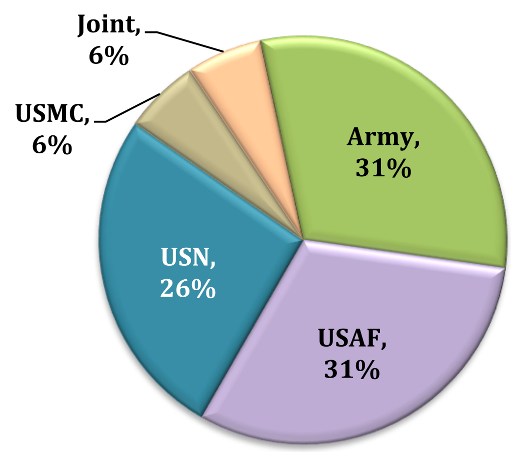

Figure 12. Breakdown by Service of the 167 Installations Surveyed in the Project

No Army Camps are included in the final list of installations surveyed. Camps were examined, but almost all of them were disqualified by virtue of being solely devoted to National Guard or Reserves, or because they were a component of a larger installation. Of the few Army Camps that were not disqualified for these reasons, none of them has WWT facilities listed in DoD databases.

The following installations were not included:

- Outside Contiguous United States installations (including in Alaska, Hawaii or the Territories)
- Academies, Postgraduate Schools, Training Centers, Colleges
- National Guard Bases
- Reserve Bases
- Air Fields (as separate units; they often occur in conjunction with larger installations)
- Air Force facilities co-located with commercial airports
- Air Force Air Refueling Wings
- Facilities of the Air Force Space Command
- Marine Corps Satellite Bases, Satellite Aviation Facilities, and Detachments
- Recruiting Depots and Stations
- Devoted medical and health facilities
- Devoted facilities for Morale, Welfare, and Recreation

[2]Any exact expression of the base count needs to be qualified due to the geographic separation that occurs with some installations. For example Joint Base San Antonio has three geographically separate, distinct components, two with on-site plants and one with off-site treatment. Defense Distribution Depot San Joaquin has two separate locations, each with a WWT plant.

- Ocean Terminals
- Miscellaneous facilities such as the Presidio, Marine Corps Henderson Hall, and Washington Navy Yard
- Other facilities that are essentially only office space

As shown in Figure 12, the installations studied spanned the Military Departments about equally, with 6% being Joint Bases.

3.1.2 Characterizing Installations

The surveyed installations were characterized using three parameters:

1) Daytime population (active military and civilians)
2) Installation footprint (area in square miles)
3) Geographic siting of the installation relative to civilian development (towns and cities).

The siting of an installation relative to development is characterized by one of the seven categorizes shown in Table 2, ranging from completely isolated to embedded within an urban area. For population and area, to facilitate analysis, each installation in the study was categorized from very small (VS) to very large (VL) (to "huge" in the case of area), as shown in Table 3. Figure 13 uses a map of San Francisco for scale, with its more or less square shape, to illustrate the range of installation areas and their corresponding size categories. A compilation of the installations examined in this study, with their categories for population, area, and siting, are provided in Appendix C.

Table 2. Categories Used to Describe the Siting of Installations Relative to Development

Isolated	Completely isolated
Separated, rural	In a rural area that has communities, but it is not adjacent to any of them
Separated, peri-urban	In a peri-urban area but separated from any community
Adjacent Town	Directly adjacent (or nearly so) to a town (fairly small community)
Adjacent Smaller City	Directly adjacent (or nearly so) to a city that is not large
Adjacent Large Metro	Directly adjacent (or nearly so) to a large metropolitan area
Embedded Urban	Embedded within an urban area

Table 3. Installation Population and Area Categories

Daytime Population	Category	Area (sq. mi.)
<500	**VS**	<1
500 – 2,500	**S**	1 - 5
2,501 – 5,000	**MS**	5 - 15
5,001 – 10,000	**M**	15 - 30
10,001 – 15,000	**ML**	30 - 50
15,001 – 25,000	**L**	50 - 70
>25,000	**VL**	70 - 200
	Huge	>200

VS, very small; S, small; M, medium small; M, medium; L, large; VL, very large

An installations area often correlates with its siting relative to development, as illustrated in Figure 14, with installations with large areas frequently (but not always) being fairly to somewhat isolated, while small installations are more frequently in urban areas and are not usually isolated. However, it is worth noting that area and siting sometimes correlate differently with various WWT factors, as will be seen in Section 3.2.2.

Figure 13. Schematic Illustration of Some Size Designations Used to Categorize Installation Areas, Using San Francisco for Scale

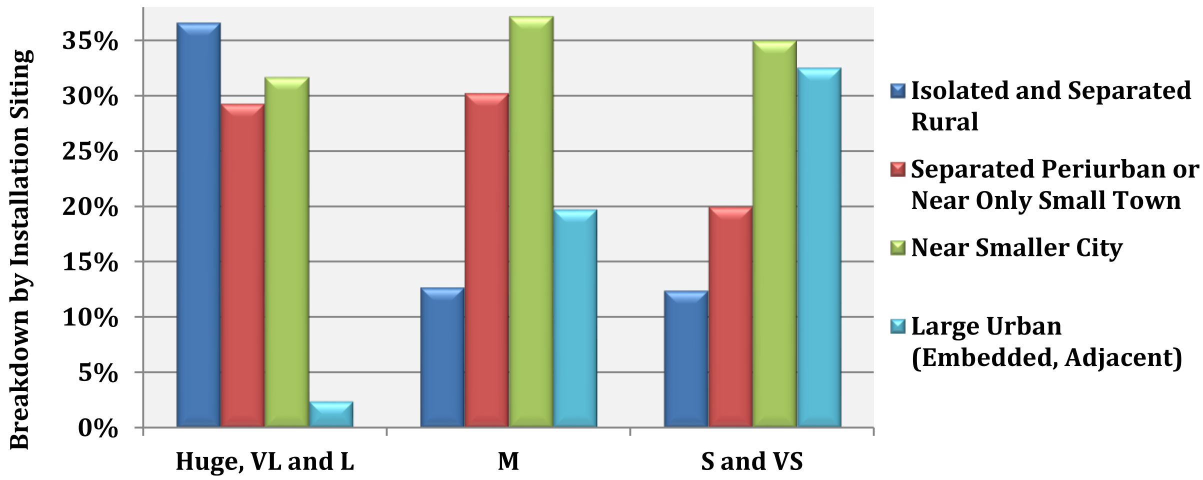

Figure 14. The Geographic Area of an Installation Often Correlates with its Siting Relative to Development

3.1.3 Characterizing DoD Wastewater Treatment

The main sources of information on WWT facilities used by installations were the following:

1) the Real Property Asset Database (RPAD) on Sewage Treatment facilities (with Facility Code 8311) and Septic Tanks, Drain Fields, and Lagoons (Facility Code 8314);
2) Military Service Databases (Army, Navy, Marine Corps, and Air Force);
3) the EPA Enforcement & Compliance History Online (ECHO) database (http://www.epa-echo.gov/echo/compliance_report_water.html); and
4) internet searching.

WWT facilities *not* included in this study were those devoted or nearly devoted to industrial wastewater, and those treating <1,000 gallons per day (0.001 million galls per day, mgd) of wastewater.

On-Site Versus Off-Site

To determine whether the wastewater for an installation is treated on-site or off, Noblis began with the list of installations as described in Section 3.1.1 and compared it to the facilities listed in the DoD databases. As a first approximation, facilities listed in DoD databases were considered on-site and installations not listed were assumed to have off-site treatment. However, the situation was often not that simple, complicated in part by the continually evolving landscape regarding both ownership and operation of facilities, and base closures and mergers. It was not uncommon for DoD databases to list facilities when WWT is actually handled off-site, and for on-site facilities to be missing from Service and/or RPAD databases. For example, a facility for Fort Bragg is still listed as active and government-owned, but an internet search found that in 2006 the adjacent municipality extended its wastewater collection infrastructure to the installation and the on-site plant is now out of service. For some installations, research was needed because the DoD databases had no facilities listed, and there were no National Pollutant Discharge Elimination System (NPDES) permits for wastewater discharge, in cases of large, relatively isolated installations where off-site treatment is unlikely. To arrive at a final pair of lists for on-site and off-site facilities serving installations, Noblis frequently used internet searching to augment information from the databases.

On-Site Facility Data

Each DoD database, to varying degrees depending on the database, provided some portion of the following data:

- **Facility Code** – Indicates whether the facility is for sewage treatment (code 8311), be it primary, secondary or advanced; less sophisticated sewage treatment (septic tanks and drain fields or settlement lagoons/ponds; code 8314 or 8315); or specifically for the treatment of industrial wastewater (83115 or 83140, depending on the database).
- **System or Real Property Asset Name** – Occasionally gives insight into level of treatment and/or type of technology used.
- **Volume Flow** – Design flow (plant capacity, in mgd), sometimes also with average flow.
- **RPA Interest Type Code** – Indicates ownership, with the two most prevalent options in this context being:
  - FEE = U.S. Government-owned property
  - PRIV = Owned by private entity, operated on federally owned land
- **RPA Operational Status Code** – Complements the ownership data in the Interest Type Code with information on facility operations:
  - ACT = active (used and operated by the government six months or more a year)
  - DISP = Conveyed or transferred to another entity
  - CARE = Minimum maintenance for safety and security
  - CLSD = closed (“mission operation ceased”).
- **Highest Treatment Level** – Pre-treatment, primary, secondary or advanced.

The Navy database also indicated whether the discharge was to a public utility (Publicly Owned Treatment Works, POTW), which helped determine on-site from off-site facilities. Three of the DoD databases (RPAD, the Navy, and the Air Force) included the year the facility was built, but the data is too uncertain to be useful. Often parts of a plant, not the entire plant, undergo improvements over the years, making the citation of a single year of questionable value. Also, the dates provided in RPAD frequently disagreed with those in the Service databases. Between the databases and internet searching, Noblis found data on the year built (or improved) for 78% of on-site facilities, but dates are not included in this report.

Table 4. Type of Data Provided by DoD Databases on Wastewater Treatment Facilities

	Facility Code	System or RPA Name	Design Flow	Average Flow	Interest Type Code	Opera-tional Status	Treat-ment Level	Discharge to POTW
RPAD	●	●	●		●	●*		
Army	●		●	●	●	●	●	
USN	●**	●	●	●				●
USMC		●	●			●*		
USAF			●	●				

**However, did not include facilities whose operation (as distinct from ownership) had been conveyed or transferred to another entity.*

***Did not include the facility code, but did provide information needed to distinguish between domestic and industrial wastewater treatment.*

Table 4 summarizes the type of data provided by each DoD database, showing that all databases except the Army's were lacking, especially with regard to treatment levels and ownership and operation arrangements. Further, there was frequent disagreement between RPAD and the Service databases. For example, it was not uncommon for the Service databases to list facilities that RPAD does not and vice versa. It was often difficult to determine if facilities for an installation listed in a Service database corresponded to the ones listed in RPAD, because the information for them differed so greatly. This was especially true of flow rates, which frequently were highly inaccurate in RPAD. (RPAD is cited as the source of inaccuracies for many flow rates because they were often much smaller than normal, in cases where Service databases listed flows typical of WWT plants.)

Gaps and discrepancies in information were addressed with internet searching, and facilitated where possible by NPDES permit numbers for the installations, which were usually obtained from the EPA ECHO database. Using NPDES numbers in internet searches sometimes led to state government discharge compliance documents which listed treatment levels and flows. (NPDES numbers were not available from DoD databases, except for occasional comments in Service databases.) The ECHO database was useful to a point for providing NPDES numbers, but many on-site DoD facilities are missing from it. Note that some facilities do not need NPDES permits because the wastewater is never discharged to a body of water other than a sewage treatment lagoon or pond.

Business Models

It is possible to determine the legal arrangement (owner and operator) for a facility if two codes are available: the Interest Type Code (indicating ownership) and the Operational Status Code (indicating operation). Of the on-site facilities in full service, the ownership/operation code combinations are:

- GOGO (government-owned, government-operated) = FEE + ACT
- GOCO (government-owned, contractor-operated) = FEE + DISP
- COCO (contractor-owned, contractor-operated) = PRIV + DISP or PRIV + ACT[3]

"Contractor" here is used broadly to include public utilities. Where Noblis was able to determine through internet searching that ownership or operation was by a POTW, a "P" was substituted for the "C", giving five business models for on-site wastewater treatment:

1) GOGO
2) GOCO
3) GOPO
4) COCO
5) POPO

The owner and operator codes were available for all Army facilities from the information provided by the Army, and in some cases for the other Services when a *government-operated* facility appeared in RPAD. (The RPAD data provided to Noblis did not include facilities whose operation had been transferred to another entity, so it was useful only for verifying GOGO arrangements.) For facilities where one or both codes were not available, Noblis assumed as a first approximation that a listed facility was GOGO, but used internet searching to try to determine if this was accurate. It should be noted, however, that the business model designations assigned to facilities in the databases cannot be entirely trusted as accurate, because it was not uncommon for a plant to be listed in a current Service

[3] Strictly speaking, a PRIV + ACT combination should indicate a facility that has been privatized but is still operated by the government, but this seems unlikely. The Army has six facilities listed as PRIV + ACT.

database as government-owned, yet for a solicitation for its privatization to have been posted on the Federal Business Opportunities web site some years earlier. In such cases, the database may still be listing a privatized facility as government-owned, or perhaps the privatization did not come through. Noblis could not always resolve these discrepancies, in which case the designation was left as GOGO.

Extent to Which Treatment Data Found

Table 5 summarizes the extent to which Noblis was able to determine the highest level of treatment used by the set of on-site plants, and the technology used. Of the 101 on-site WWT plants in this study, at least some information on wastewater treatment was found for over 85% of them (all but 15). Of the 87 plants with treatment information, the most common blank was the specific technology used for the plants using only primary treatment. However, this information is not essential in the context of the project objectives, since primary treatment by definition consists essentially of the removal of a large quantity of solids by settling (and sometimes skimming), be it in tanks or ponds. On the other end of the treatment spectrum, for about a third of the facilities using advanced treatment technologies, Noblis was not able to determine the type of secondary treatment preceding the final, advanced treatment. Also, Noblis was usually not able to determine, during this preliminary stage of the project, the exact types of advanced treatments applied. However, for those facilities determined to be using either secondary or advanced treatment, Noblis was able to determine the type of secondary technology for 91% of them.

Table 5. Extent to Which Highest Treatment Level and Treatment Technology Were Determined for On-Site Plants

Treatment Level and Treatment Technology Determined	# of WWT Facilities
No treatment information found	15
Only primary or pre-treatment treatment used	17
Secondary or advanced treatment used, secondary technology known	**64**
Secondary treatment used, technology NOT known	1
Advanced treatment, preceding secondary technology NOT known	4
Total On-Site WWT Facilities	**101**

Final Dataset for On-Site Treatment Facilities

The final set of data for this preliminary stage of the project is compiled in Appendix D. For each WWT facility, the following data is provided where available [the availability of data as a percent of on-site installations is given in brackets]:

- *Business Model* – GOGO, GOCO, GOPO, COCO, or POPO. [Availability: 100%]
- *Plant Capacity* – in terms of daily design volume flow. [Availability: 100%]
- *Highest Level of Treatment* – preliminary only (screening and/or preliminary settling), primary, secondary, or advanced (tertiary). [Availability: 85%]
- *Type of Technology Used* – for highest level of treatment, except for advanced treatment, for which technologies generally not determined. [Availability: 74% for those that treat to a secondary level of treatment or less; 91% for those facilities determined to be using either secondary or advanced treatment]
- *NPDES Permit Number* – not relevant for all facilities [Availability: 55%]

3.2 Data Analysis

3.2.1 Trends in the Use of On-Site versus Off-Site Wastewater Treatment

Out of 167 installations included in this phase of the project, a little over half of them (53%) have at least one on-site WWT facility. Eleven installations have more than one facility on-site. As expected, the strongest predictor of whether an installation has its wastewater treated on-site or off is its distance from civilian development. As shown in Figure 15, installations that are isolated (either completely or in rural areas with little development in the vicinity) always treat their wastewater on-site. By a similar logic, installations embedded within urban areas always use nearby public utilities for their WWT, and only three of the 23 installations in close proximity to a large metropolitan area have their wastewater treated on-site.

Figure 15. On-Site versus Off-Site WWT Strongly Correlates with Distance from Development

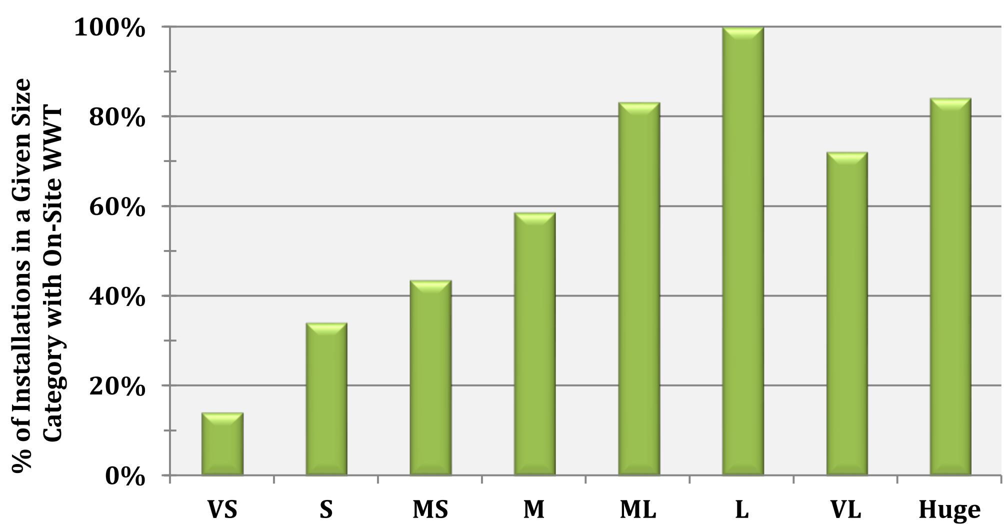

Figure 16. On- versus Off-Site WWT Strongly Correlates with Installation Area

There is also a strong correlation with the geographic area of an installation, as demonstrated by Figure 16: installations that are medium-large or larger are significantly more likely to have on-site WWT, while installations with very small to medium-small areas more often have their wastewater treated off-site. The daytime population of an installation, however, has little if any bearing on whether wastewater is treated on- or off-site.

Across the Military Services, the trend seen in Figure 17 for the Marines Corps and Army to more frequently have on-site wastewater treatment follows the tendency—as illustrated by Figures 18 and 19 for all installations in the study— for these Services to have larger and more isolated installations.

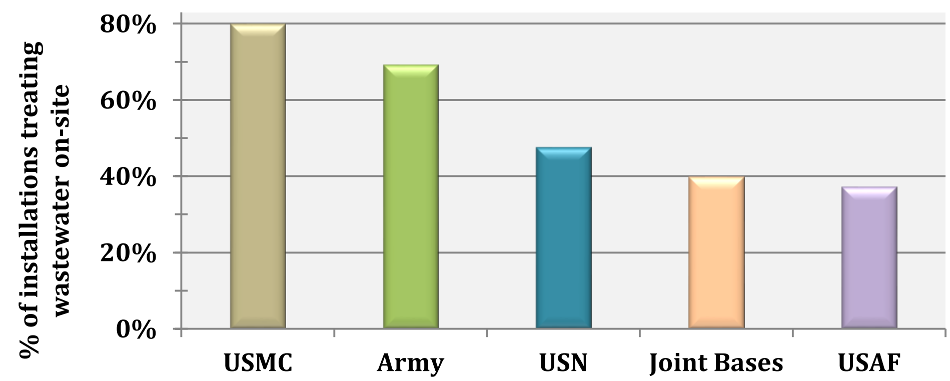

Figure 17. The Marines Corps and Army Are More Likley to Treat Wastewater On-Site

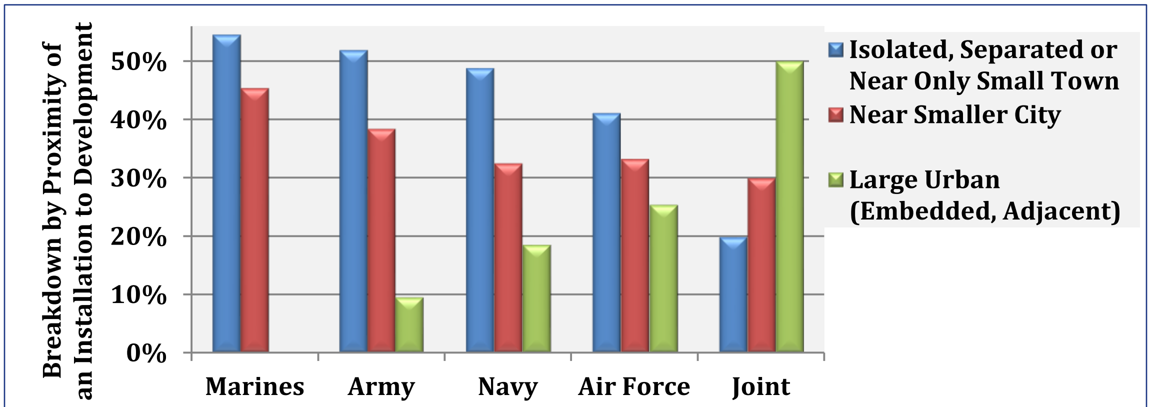

Figure 18. Difference in Installation Siting Across the Military Services (all facilities)

3.2.2 Trends in Wastewater Treatment Approaches Used by Installations with On-Site Facilities

Facility Design Capacity and Flow Rates

Flow rates are principally of interest in this project for purposes of examining the correlation of various WWT approaches with facility design flow (the capacity, or size, of the facility). These correlations are discussed in the sections that follow. In addition, Noblis explored the correlation between the daytime population of installations and WWT flows. Not surprisingly, there was very little correlation with the *design* flow, since actual flows are almost always considerably smaller than the design flow. (Noblis was able to obtain *average* flows for only 59% of on-site WWT facilities in this study, but on average for this

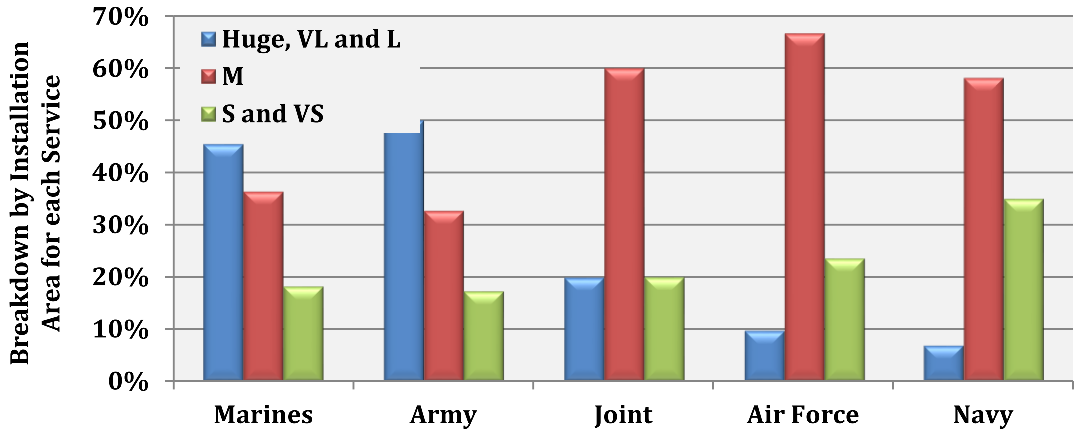

Figure 19. Difference in Installation Areas Across the Military Services (all facilities)

subset the average flow was a little less than half of the design flow (45% ± 20%).) The correlation between population and flow is much better when *average* flows are used (see Figure 20), although the correlation is still not tight due to variables in installation conditions and the fact that population numbers on many installations are approximations due to constant fluctuations. The linear regression gives an average volume of wastewater generated per person per day of 66 gallons. This volume is in line with residential wastewater flows in the United States of approximately 69 gallons per person per day.[4]

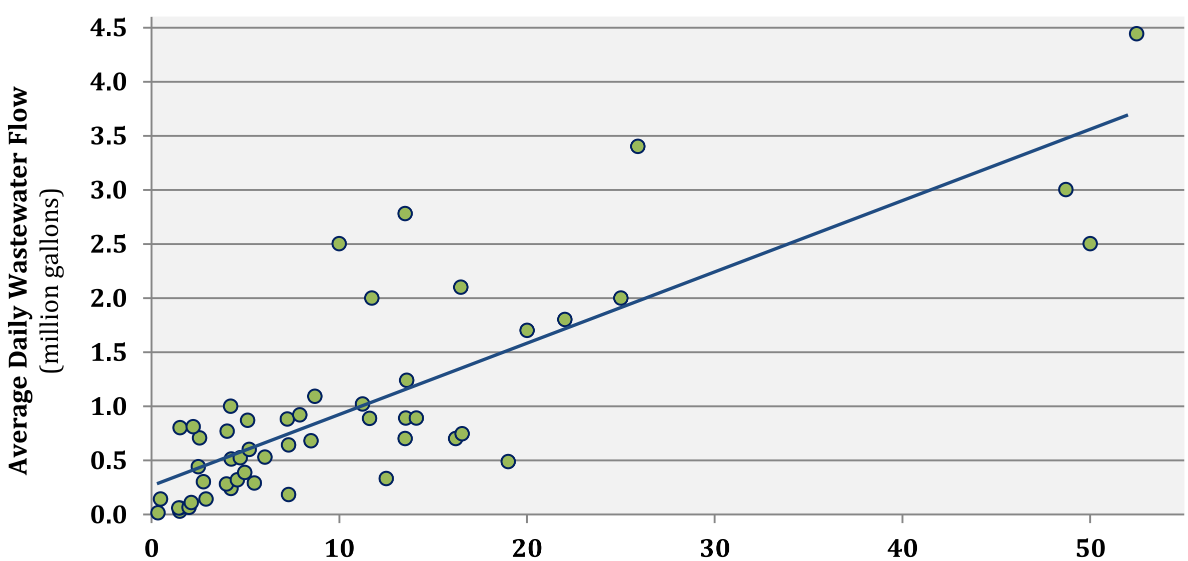

Figure 20. Correlation Between Average Flow (mgd) and Daytime Population (in 000s)
(6 outliers removed where most wastewater clearly treated elsewhere)

[4] From the weighted average of three studies. Source: *Onsite Wastewater Treatment Systems Manual*, February 2002, Office of Water Office of Research and Development, EPA, EPA/625/R-00/008.

Business Models

The fact that infrastructure is located on a military installation no longer corresponds with DoD ownership. Of the 101 WWT facilities in this study that are located on installations, 14 % of them are not owned by the government: 12% are owned (and operated) by contractors, and 2% by public utilities (Figure 21). Among the 88 facilities that are owned by the government, seven are operated by other entities: six by private-sector contractors and one by a POTW.

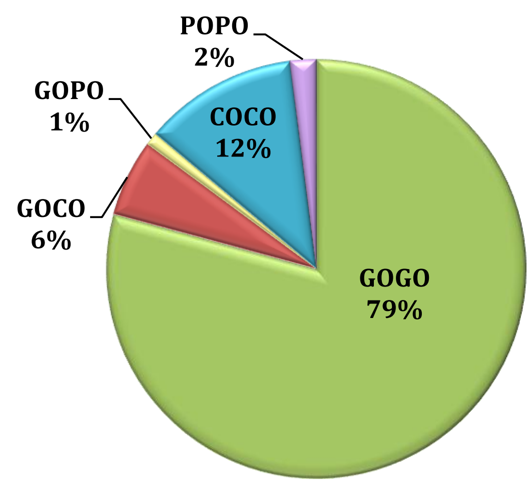

Figure 21. Distribution of Different Owner/Operator Business Models Across On-Site WWT Facilities

The data reveal a number of trends for business models. With regard to the siting of an installation, alternative business models are more prevalent away from urban areas. There are no such facilities either near or embedded within a large urban area; 60% are in the vicinity of a smaller city or small town; and 40% are isolated (either completely or in rural areas separated from any community). Alternate business models are more common in facilities with advanced treatment. Of the 16 facilities with advanced treatment, 38% of them use an alternative business model. This is about double the frequency occurring in facilities whose highest level of treatment is either secondary or primary. Finally, for plant capacity, although COCO facilities span the entire range of sizes from very small to very large, COCO facilities have a tendency to be large, with 75% having medium-large, large or very large capacity (Figure 22). The other alternative business models were spread fairly evenly over the different facility size categories.

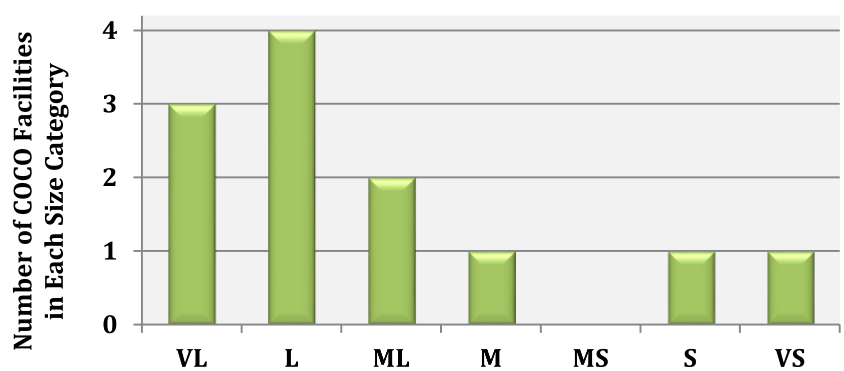

Figure 22. Large On-Site Facilities Are More Likely to Use a Contractor Owned-Contractor Operated Business Model

Perhaps the most interesting observation regarding business models is the distribution of alternative business models across the Military Services: of the 20 facilities using alternative business models, 16 of them (80%) are Army. The Air Force has three alternative models, the Marines Corps and Joint Bases just one each, and the Navy none. Further, all four alternative models used by the other Services are the most traditional option: GOCOs. The Army, by contrast, has a dozen installations where the on-site

WWT facility is not only operated by a private entity but owned as well, the only Service with such arrangements (of the installations in this study). The Army also has the only examples in this study of arrangements with public utilities, both GOPO and POPO.

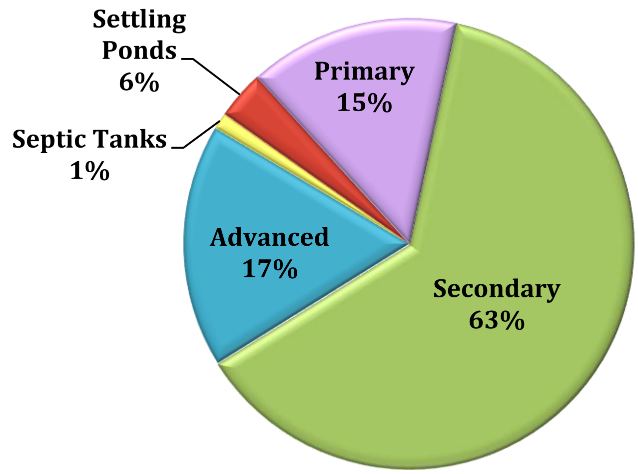

Figure 23. Treatment Levels Used by Installations with On-Site Wastewater Treatment
(of plants for which treatment level known)

Treatment Level

Of the 86 facilities in the study for which the highest level of treatment is known, secondary treatment far outstrips other options, as shown in Figure 23. Only one in six plants use advanced treatment, and 15% are constrained to primary treatment only. Only four installations use septic lagoons or settlement ponds that do not achieve even a primary level of treatment, and one installation relies on septic tanks (in an area where civilian development also relies heavily on septic tanks). Across the Services, Figure 24 reveals that the Air Force and Navy seldom use advanced treatment. Otherwise, the distribution of treatment levels is fairly uniform, with the notable exception of the Marines Corps whose highest level of treatment is always either advanced or secondary, with equal frequency (for the ten out of 12 bases for which the treatment level is known).

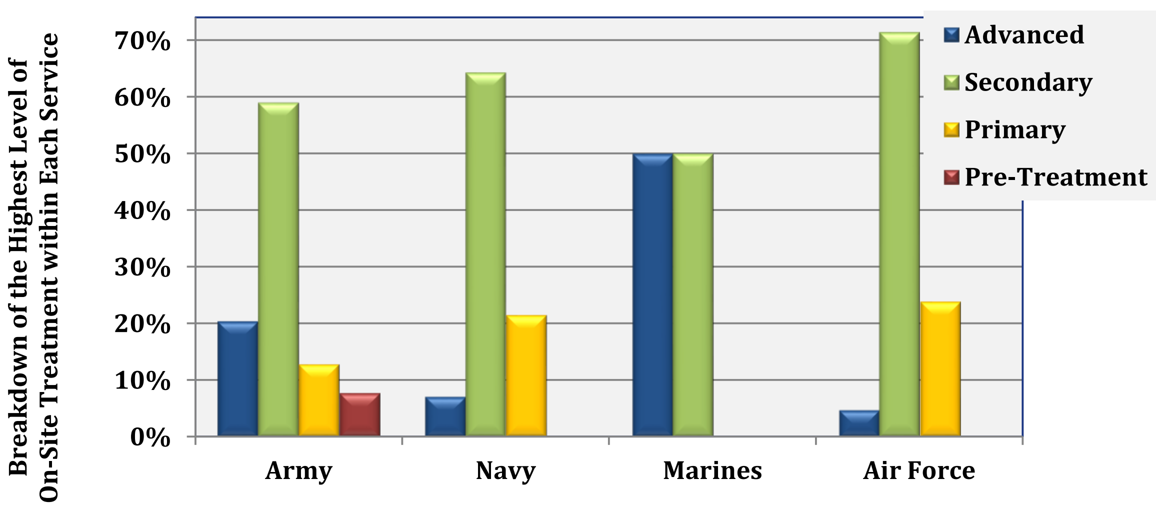

Figure 24. Highest Wastewater Treatment Levels Used Across the Services

As expected since secondary treatment is by far most prevalent, its occurrence is spread fairly evenly across the various factors: the Services, facility capacity (size in terms of flow), and the

installations' geographic siting and area. Noblis examined whether any trends or drivers exist for the less common levels of treatment. For facility size, Table 6 presents a matrix of the number of facilities in each size category for each level of wastewater treatment.[5] The results are depicted graphically in Figure 25, with the breakdown by highest treatment level plotted in each facility size category. The bar chart shows that secondary treatment dominates in the medium-size facilities, but advanced treatment is considerably more prevalent among facilities with large and very large design flows. A restriction to primary treatment occurs more frequently among the small and very small facilities than it does in the other size categories.

Table 6. Correlation Between Facility Size (Flow Capacity) and Highest Treatment Level

Size \ Level		Adv	Sec	Pri	Pre-Tr	Totals (Sizes) #	Totals (Sizes) %
VL		4	1	0	1	6	**7%**
L		6	5	3	0	14	**15%**
ML		1	20	4	0	25	**29%**
M		1	16	1	0	18	**21%**
MS		0	6	0	0	6	**7%**
S		1	4	4	1	10	**12%**
VS		2	2	1	1	6	**7%**
Totals (Levels)	#	15	54	13	3	85	100%
	%	**18%**	**64%**	**15%**	**4%**	100%	

Adv = advanced, Sec = secondary, Pri = primary, Pre-Tr = Pre=Treatment

There is one other factor exhibiting a parallel with the occurrence of advanced treatment: large geographic area. As displayed in Figure 26, installations with large to huge areas had almost three times as many facilities with advanced treatment than installations with medium areas (MS to ML); no advanced facilities existed on installations with small and very small areas. No such correlation exists for facilities limited to primary treatment. Noblis also did not observe any clear relationship between the highest treatment level and the geographic siting of the installation.

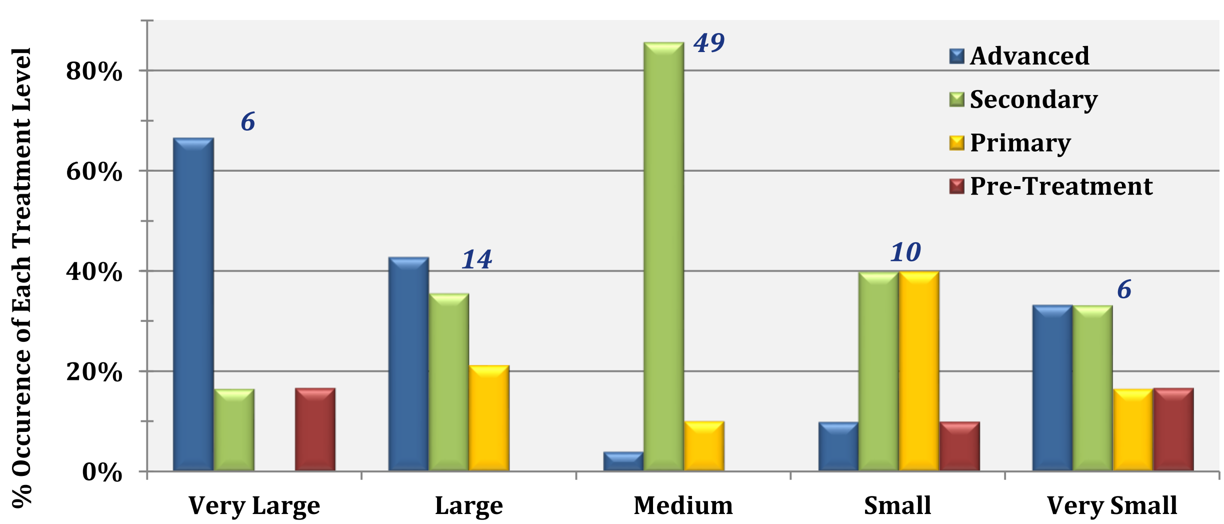

Figure 25. The Dependence of Wastewater Treatment Level on the Size (Flow Capacity) of the Wastewater Treatment Facility
(the number of facilities in each size category given in italics)

[5] The table shows 85 facilities rather than 86 because the Naval Base relying on septic tanks is not included.

Treatment Technology

This section of the report discusses trends and correlations between the type of WWT technology in use on installations and a variety of factors. It is important to offer the caveat, however, that in many cases choices on technology were made many years ago, and some factors—notably installation population and the amount of development around the installation—have changed since then.

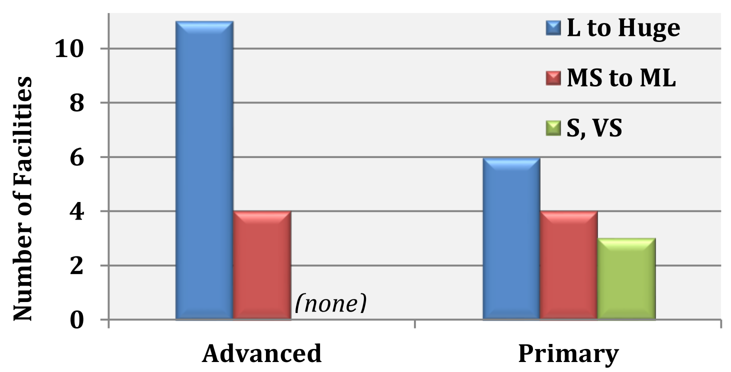

Figure 26. Installation Area Correlates to the Occurrence of Advanced Treatment, but Not Primary

DoD installations are conventional when it comes to wastewater treatment technologies. Of the 63 facilities for which Noblis was able to determine the type of secondary technology being used, fully three-quarters use either trickling filter or activated sludge (Figure 27), reflecting the popularity of these two process among the general population of WWT plants. Of the group in this study, seven secondary treatment processes were represented, but most of the facilities—seven out of eight—were using one of four technologies: trickling filter (38%), activated sludge (29%), oxidation ponds (13%), or oxidation ditch (9%). In addition to the set of known secondary technologies, treatment approaches were determined for nine other facilities: seven of the 13 primary treatment facilities are known to be ponds or lagoons, and all three pre-treatment facilities are settling ponds. This brings the data set of known treatment processes to 73.

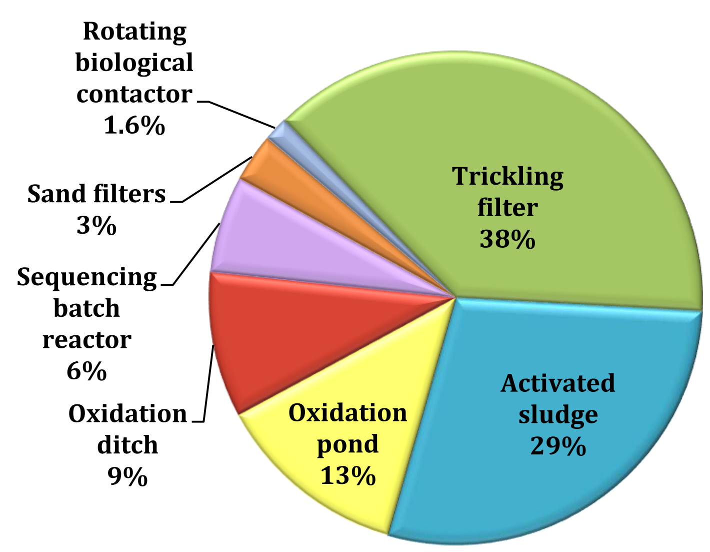

Figure 27. Type of Secondary Treatment Technologies Used by On-Site WWT Facilities
(for the 63 facilities for which known)

Out of this set of 73, the sole use of ponds or lagoons for wastewater treatment was not uncommon. One-quarter of facilities (18) relied solely on some sort of pond or lagoon for WWT, spanning all levels of treatment: pre-treatment (3 facilities) , primary (7), and secondary (8). Although almost a third of these installations are in the "huge" category for area, the other installations using only lagoons for treatment range from small to medium-large, so there is not a strong correlation between a reliance on lagoons and installation area. The stronger correlation is with relative isolation: ten of the installations were isolated (completely or nearly so), eight were in a periurban area separated from any community or were near only a small town, and just one was close to a smaller city.

One surprising finding is the variation in treatment approaches employed across the Military Services (Figure 28). (The two Joint Bases for which the treatment technology is known—Joint Base Lewis-McChord and Joint Base San Antonio Camp Bullis—were combined with the Army for this analysis.) The Army strongly favored trickling filters, and uses none of the less common processes. By contrast, the Navy used no trickling filters at all, preferring activated sludge, and a quarter of their technologies are the less common varieties (rotating biological contactor, sand filter, and sequencing batch reactor). The profile for the Marines Corps is similar in this regard, but a quarter of its facilities used trickling filters compared to none for the Navy. The profile for the Air Force is different yet again, with 37% of its facilities using either primary or secondary ponds or lagoons.

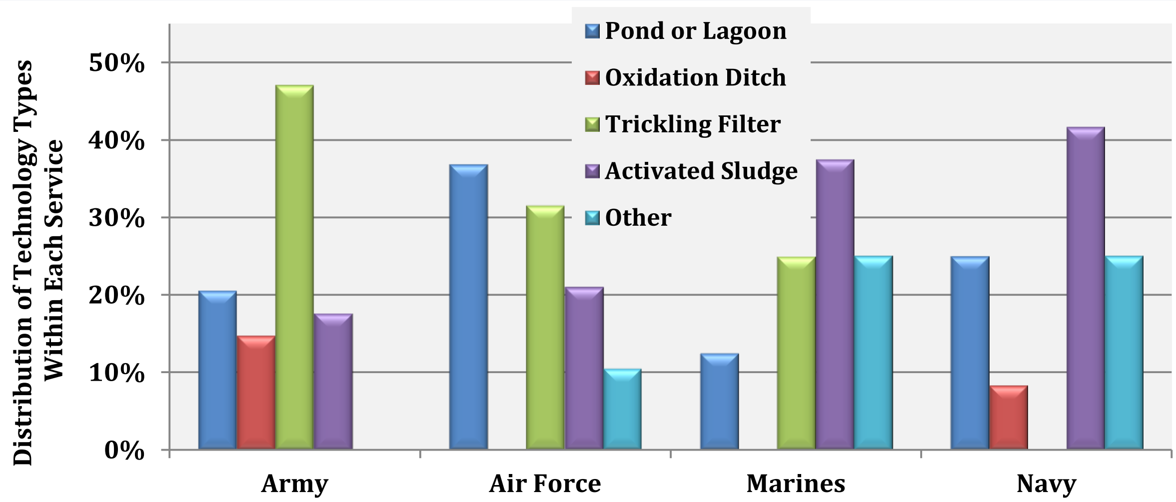

Figure 28. Treatment Technology Choices Vary Considerably Across the Services

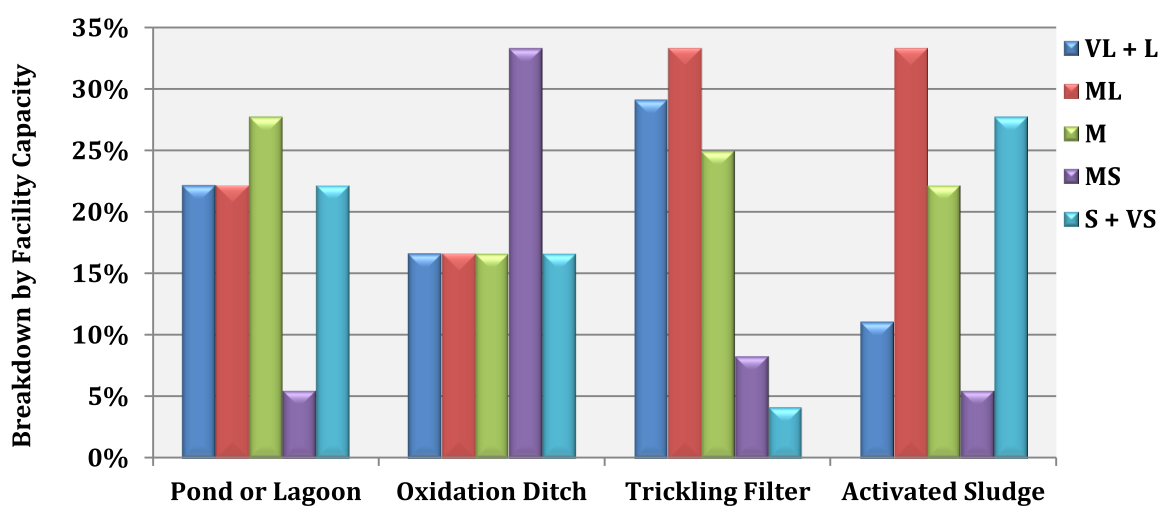

Figure 29. Facility Capacity Has Some Bearing on Choice of Treatment

There are some trends that can be observed in Figure 29 between treatment technology (secondary, plus all ponds and lagoons, regardless of treatment level) and the size of the facility in terms of design

flow. The two most common technologies, activated sludge and trickling filters, have very different profiles with regard to facility capacity. Activated sludge was used in quite a few small and very small facilities, but by only one large and one very large facility. Trickling filters skew the other direction, favored more by facilities with large capacities, with very few medium-small to very small facilities using this process. An influencing factor may be that the higher initial capital costs for trickling filters make it a less popular choice for smaller facilities. There were only six oxidation ditches in the study, making it difficult to identify trends, but the data is consistent with the fact that the large footprint and long retention time for this technology make it unsuitable for large flows. There was only one large facility and one medium-large using the oxidation ditch, with the other four ranging from medium to very small capacity. Ponds and lagoons occurred across the spectrum of facility capacities, showing little correlation with flow.

Installation area by itself is not a good parameter to analyze for correlations with treatment technologies, because some installations have an abundance of undeveloped land far beyond that relevant for the choice of technology, while others are densely populated. A better but related parameter is population density. To facilitate the evaluation of data, average installation densities were grouped into categories from very low to very high density as shown in Table 7. (Noblis based the assignment of categories on the installations relative to one another, not on civilian development densities. For example, although citations of suburban density vary greatly, it can be considered to be roughly between 1,000 and 3,000 people per square mile. For urban areas, the density of Denver, Colorado is 3,700 people per square mile, while Washington, D.C. is approaching 10,000. DoD installations are generally considerably less dense than civilian development, with only ten installations falling into the high or very high density category.[6])

Table 7. Average Installation Density Categories
(people per square mile)

Very Low	1 - 100
Low	101 - 400
Medium	401 - 2000
High	2001 - 4000
Very High	>4000

The population density categories are graphed in Figure 30 for the four most common treatment technologies, revealing some trends. First, ponds and lagoons serving as the sole treatment for domestic wastewater were absent on installations with high or very high density, as were oxidation ditches, consistent with the relatively large areas of these approaches. The occurrence of ponds and lagoons, in particular, steadily declined as density increased. Trickling filters were present more frequently on less dense installations, compared to activated sludge, with both high density installations using activated sludge. This trend is consistent with the larger land requirement for trickling filters compared to activated sludge, and due to the fact that—for a given footprint—the activated sludge process requires less time to achieve a given effluent quality. This reduced time, however, does come with an energy cost.

There is little correlation between the type of business model for a facility and its treatment technology. Of the facilities for which the treatment technology process is known, 13 have alternative business models. They are dominated by the two most common types of technologies: seven of them use trickling filters and four use activated sludge.

Focusing on just the type of *secondary* technology used by a WWT facility, the data reveal a clear correlation with an installation's proximity to development. Figure 31 plots the occurrence of the four

[6] The very high density installations are Fort Meade, MD with 6,000 people per square mile; Naval Base Kitsap Bangor, WA with about 6,300; and Naval Air Station Patuxent River Webster Field Annex, MD with 8,500. Densities for all installations are approximations, given the constantly fluctuating population at many of them.

most common types of secondary treatment technologies across three siting categories: mostly isolated, fairly urban, and in between these. The graph reveals a correlation of relative isolation with technology type that follows the order:

Pond or Lagoon > Oxidation Ditch > Trickling Filter > Activated Sludge

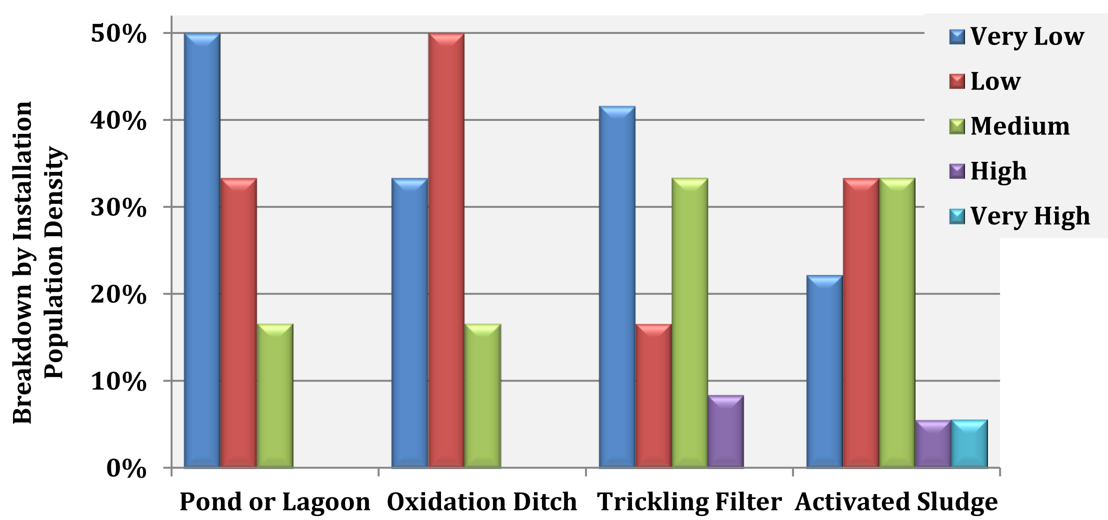

Figure 30. Correlation between the Population Density of Installations and Treatment Technology

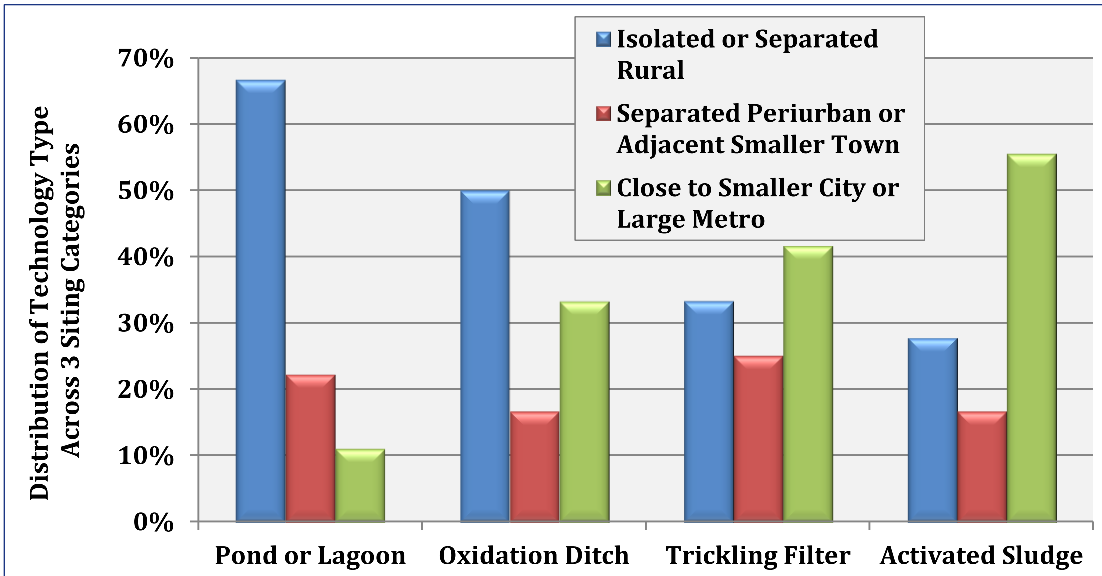

Figure 31. Treatment Technology as a Function of Proximity to Development

where there is a declining likelihood going from left to right for the technology to be in an isolated area, and an increasing likelihood for it to be in an urban area. That is, ponds and lagoons are most common in more isolated areas, and activated sludge is the most prevalent secondary technology in more urban settings. As noted earlier, ponds or lagoons for all treatment levels are more prevalent in more isolated areas, and secondary ponds and lagoons follow this trend. Not surprisingly, the greater prevalence of activated sludge in more urban areas tracks this same tendency with population density.

Appendix A: Acronyms

AFB	Air Force Base
BOD	biological oxygen demand
JB	Joint Base
L	large
M	medium
MCAS	Marine Corps Air Station
MCB	Marines Corps Base
MCLB	Marines Corps Logistics Base
MCRD	Marines Corps Recruit Depot
mgd	million gallons per day
ML	medium-large
MS	medium-small
NAF	Naval Air Facility
N_2O	nitrogen dioxide
NAS	Naval Air Station
NAWS	Naval Air Weapons Station
NSA	Naval Support Activity
NSB	Naval Submarine Base
NSF	Naval Support Facility
NSF	National Science Foundation
POTW	Publicly Owned Treatment Works
R&D	research and development
RPA	Real Property Asset
RPAD	Real Property Asset Database
S	small
TSS	total suspended solids
UV	ultraviolet
VS	very small
VL	very large
WWT	wastewater treatment

Appendix B: Lists of Tables and Figures

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List of Figures

Appendix C: Compilation of Installations in Study and Their Key Characteristics

See Tables 2 and 3 for the definitions of the three categories used in the following tables (daytime population, installation area, and siting). The Military Services are distinguished by color coding: Army green, Air Force purple, Navy blue, Marines Corps tan, and Joint Bases orange.

Installations with On-Site Wastewater Treatment

Installation Name	Serv-ice	ST	Pop. (Day)	Area		Pop. Density		Siting Relative to Development
				sq mi	Cat.	/sq mi	Cat.	
Aberdeen Proving Ground	A	MD	ML	114	VL	119	low	Adjacent Town
Anniston Army Depot	A	AL	MS	25	M	170	low	Adj-Smaller City
Arnold AFB	AF	TN	VS	8	MS	52	v. low	Adj-Smaller City
Beale AFB	AF	CA	M	34	ML	153	low	Separated, rural
Blue Grass Army Depot	A	KY	S	23	M	45	v. low	Adj-Smaller City
Cannon AFB	AF	NM	M	6	MS	868	med.	Separated, rural
Creech AFB	AF	NV	S	4	S	672	med.	Isolated
Defense Distribution Depot San Joaquin - West Sharpe	A	CA	S	2	S	810	med.	Adj-Smaller City
Defense Distribution Depot San Joaquin - West Tracy	A	CA	S	0.7	VS	2,133	high	Adj-Smaller City
Dugway Proving Ground	A	UT	S	618	Huge	2	v. low	Isolated
Edwards AFB	AF	CA	M	483	Huge	21	v. low	Separated, periurban
Eglin AFB	AF	FL	ML	640	Huge	21	v. low	Separated, periurban
Ellsworth AFB	AF	SD	MS	7	MS	552	med.	Adj-Smaller City
Fort A.P. Hill	A	VA	S	117	VL	18	v. low	Isolated
Fort Benning	A	GA	VL	284	Huge	112	low	Adj-Smaller City
Fort Campbell	A	KY	VL	160	VL	214	low	Separated, rural
Fort Carson	A	CO	L	586	Huge	38	v. low	Adj-Smaller City
Fort Detrick	A	MD	M	2	S	2,900	high	Adj-Smaller City
Fort Hood	A	TX	VL	363	Huge	187	low	Adj-Smaller City
Fort Huachuca	A	AZ	ML	129	VL	105	low	Adjacent Town
Fort Irwin	A	CA	ML	915	Huge	12	v. low	Isolated
Fort Leonard Wood	A	MO	L	100	L	165	low	Isolated
Fort McCoy	A	WI	MS	93	VL	44	v. low	Adjacent Town
Fort Meade	A	MD	VL	8	MS	5,952	v. high	Adj-Smaller City
Fort Polk	A	LA	ML	296	Huge	40	v. low	Separated, rural
Fort Riley	A	KS	VL	157	VL	171	low	Separated, rural
Fort Rucker	A	AL	ML	99	VL	139	low	Separated, rural

Installation Name	Serv -ice	ST	Pop. (Day)	Area sq mi	Area Cat.	Pop. Density /sq mi	Pop. Density Cat.	Siting Relative to Development
Fort Sill	A	OK	L	149	Huge	134	low	Adjacent Town
Fort Stewart	A	GA	L	437	Huge	56	v. low	Adjacent Town
Fort Stewart - Hunter Army Airfield	A	GA	M	2	S	3,223	high	Adj-Smaller City
Grand Forks AFB	AF	ND	S	8	MS	191	low	Isolated
Hawthorne Army Depot	A	NV	M	230	Huge	25	v. low	Isolated
Holloman AFB	AF	NM	MS	82	L	51	v. low	Separated, rural
Iowa Army Ammunition Plant	A	IA	ML	30	ML	475	med.	Adj-Smaller City
Joint Base Lewis-McChord	JB	WA	VL	136	VL	36	v. low	Adj-Smaller City
Joint Base McGuire-Dix-Lakehurst	JB	NJ	VL	66	L	734	med.	Separated, rural
Joint Base San Antonio - Camp Bullis	JB	TX	VL	45	ML	936	med.	Adj-Smaller City
Joint Base Charleston	JB	SC	MS	5	MS	141	low	Adj-Smaller City
Laughlin AFB	AF	TX	S	8	MS	292	low	Adj-Smaller City
MacDill AFB	AF	FL	L	9	MS	2,159	high	Adj-Lg Metro Area
MCAGCC 29 Palms	MC	CA	L	998	Huge	16	v. low	Adj-Smaller City
McAlester Army Ammunition Plant	A	OK	VS	70	VL	2	v. low	Adj-Smaller City
McAlester Plant - Camp Stanley Storage Activity	A	TX	S	6	MS	320	low	Adj-Lg Metro Area
MCAS Beaufort	MC	SC	MS	11	MS	436	med.	Adjacent Town
MCAS Cherry Point	MC	NC	ML	19	M	766	med.	Separated, rural
MCB Camp Lejeune	MC	NC	VL	240	Huge	219	low	Adjacent Town
MCB Camp Pendleton	MC	CA	VL	191	VL	197	low	Adj-Smaller City
MCB Quantico	MC	VA	M	97	VL	90	v. low	Adj-Smaller City
MCLB Albany	MC	GA	MS	5	S	633	med.	Adj-Smaller City
MCLB Barstow	MC	CA	S	10	MS	198	low	Separated, rural
MCRD Parris Island	MC	SC	MS	13	MS	205	low	Adjacent Town
Minot AFB	AF	ND	ML	8	MS	1,489	med.	Isolated
Moody AFB	AF	GA	MS	17	M	300	low	Separated, rural
Mountain Home AFB	AF	ID	S	4	S	714	med.	Isolated
NAF El Centro	N	CA	VS	4	S	112	low	Separated, rural
NAS Corpus Christi	N	TX	M	6	MS	1,316	med.	Adj-Smaller City
NAS Fallon	N	NV	MS	121	VL	33	v. low	Separated, rural
NAS Jacksonville	N	FL	L	9	MS	1,884	med.	Adj-Lg Metro Area
NAS Key West	N	FL	MS	7	MS	439	med.	Adj-Smaller City

Installation Name	Serv-ice	ST	Pop. (Day)	Area sq mi	Area Cat.	Pop. Density /sq mi	Pop. Density Cat.	Siting Relative to Development
NAS Kingsville	N	TX	S	11	MS	135	low	Adj-Smaller City
NAS Lemoore	N	CA	M	47	ML	181	low	Separated, periurban
NAS Patuxent River Webster Field Annex	N	MD	L	2	S	8,500	v. high	Separated, rural
NAS Whidbey Island - Ault Field	N	WA	ML	13	MS	1,000	med.	Adj-Smaller City
Naval Magazine Indian I.	N	WA	VL	11	MS	12	v. low	Separated, periurban
NAWS China Lake	N	CA	VS	22	M	103	low	Isolated
NB Kitsap, Bangor	N	WA	VS	4	S	6,338	v. high	Separated, periurban
NB Ventura County San Nicolas Island	N	CA	S	1,719	Huge	0.2	v. low	Adjacent Town
NS Mayport	N	FL	L	5	MS	3,115	high	Separated, periurban
NSA Crane	N	IN	MS	98	VL	51	v. low	Separated, rural
NSA Northwest Annex, Chesapeake	N	VA	S	6	MS	262	low	Separated, periurban
NSB Kings Bay	N	GA	M	25	M	296	low	Separated, rural
NSF Dahlgren	N	VA	MS	7	MS	677	med.	Adjacent Town
NSF Indian Head	N	MD	MS	5	MS	550	med.	Adjacent Town
NWS Earle	N	NJ	S	16	M	128	low	Adjacent Town
Picatinny Arsenal	A	NJ	M	10	MS	540	med.	Adjacent Town
Pine Bluff Arsenal	A	AR	S	21	M	57	v. low	Separated, rural
Red River Army Depot	A	TX	ML	28	M	427	med.	Adj-Smaller City
Redstone Arsenal	A	AL	VL	60	L	433	med.	Adj-Smaller City
Robins AFB	AF	GA	L	14	MS	1,818	med.	Adjacent Town
Savanna Army Depot	A	IL	VS	20	M	20	v. low	Separated, rural
Schriever AFB	AF	CO	S	5	S	449	med.	Separated, periurban
Scott AFB	AF	IL	ML	5	S	2,608	high	Separated, periurban
Shaw AFB	AF	SC	M	5	MS	1,158	med.	Adjacent Town
Tobyhanna Army Depot	A	PA	MS	2	S	2,220	high	Separated, rural
Tooele Army Depot	A	UT	S	37	ML	27	v. low	Adjacent Town
White Sands Missile Range	A	NM	MS	3,421	Huge	1	v. low	Isolated
Whiteman AFB	AF	MO	MS	6	MS	787	med.	Adjacent Town
Yuma Proving Ground	A	AZ	L	1,316	Huge	13	v. low	Isolated

Installations with Off-Site Wastewater Treatment

Installation Name	Serv-ice	ST	Pop. (Day)	Area sq. mi.	Area Cat.	Siting Relative to Development
Altus AFB	AF	OK	MS	5	MS	Adj-Smaller City
Barksdale AFB	AF	LA	M	34	ML	Adj-Lg Metro Area
Buckley AFB	AF	CO	M	5	MS	Adj-Smaller City
Columbus AFB	AF	MS	MS	8	MS	Separated, periurban
Davis-Monthan AFB	AF	AZ	M	17	M	Adj-Lg Metro Area
Dover AFB	AF	DE	MS	6	MS	Adj-Smaller City
Dyess AFB	AF	TX	M	10	MS	Adj-Smaller City
F.E. Warren AFB	AF	WY	MS	9	MS	Adj-Smaller City
Fairchild AFB	AF	WA	MS	9	MS	Separated, periurban
Fort Belvoir	A	VA	M	15	MS	Adjacent Town
Fort Bliss	A	TX	VL	1,048	Huge	Adj-Smaller City
Fort Bragg	A	NC	VL	251	Huge	Adj-Smaller City
Fort Devens	A	MA	VS	8	MS	Separated, periurban
Fort Gordon	A	GA	L	87	VL	Separated, periurban
Fort Hamilton	A	NY	S	0.01	VS	Embedded Urban
Fort Jackson	A	SC	M	81	VL	Adj-Smaller City
Fort Knox	A	KY	ML	170	VL	Adjacent Town
Fort Leavenworth	A	KS	M	9	MS	Adj-Smaller City
Fort Lee	A	VA	M	9	MS	Embedded Urban
Fort McPherson	A	GA	M	0.8	VS	Adj-Lg Metro Area
Goodfellow AFB	AF	TX	M	2	S	Adj-Smaller City
Hanscom AFB	AF	MA	MS	1	S	Adjacent Town
Hill AFB	AF	UT	L	10	MS	Adj-Smaller City
JB Anacostia-Bolling	JB	DC	ML	1	S	Adj-Lg Metro Area
JB Andrews-Naval Air Facility Wash.	JB	MD	L	8	MS	Adjacent Town
JB Langley-Eustis	JB	VA	L	18	M	Adj-Lg Metro Area
JB Myer Henderson Hall	JB	TX	ML	11	VS	Adj-Lg Metro Area
JB San Antonio-Lackland	JB	TX	VL	6	MS	Adj-Lg Metro Area
JB San Antonio-Randolph	JB	VA	ML	0.42	MS	Adj-Lg Metro Area
Keesler AFB	AF	MS	M	2	S	Embedded Urban
Kirtland AFB	AF	NM	M	81	VL	Adj-Lg Metro Area
Lake City Army Ammunition Plant	A	MO	VS	6	MS	Adj-Smaller City
Letterkenny Army Depot	A	PA	S	28	M	Adjacent Town
Little Rock AFB	AF	AR	M	9	MS	Separated, periurban
Los Alamitos Joint Forces Training Base	A	CA	S	2	S	Embedded Urban

Installation Name	Serv-ice	ST	Pop. (Day)	Area		Siting Relative to Development
				sq. mi.	Cat.	
Los Angeles AFB	AF	CA	MS	0.2	VS	Embedded Urban
Luke AFB	AF	AZ	M	7	MS	Separated, periurban
Malmstrom AFB	AF	MT	MS	5	MS	Adj-Smaller City
Maxwell-Gunter AFB	AF	AL	L	2	S	Adj-Lg Metro Area
MCAS New River	MC	NC	M	4	S	Adjacent Town
MCAS Yuma	MC	AZ	ML	4,375	Huge	Adj-Smaller City
McConnell AFB	AF	KS	MS	4	S	Adj-Lg Metro Area
NAB Little Creek	N	VA	ML	3	S	Adj-Smaller City
NAS Meridian	N	MS	S	13	MS	Adjacent Town
NAS Oceana	N	VA	ML	9	MS	Adj-Smaller City
NAS Patuxent River	N	MD	ML	10	MS	Adjacent Town
NAS Pensacola	N	FL	L	9	MS	Adj-Smaller City
NAS Whiting Field	N	FL	MS	19	M	Adjacent Town
NB Coronado	N	CA	VL	14	MS	Adj-Lg Metro Area
NB Kitsap, Bremerton	N	WA	VL	16	M	Adj-Smaller City
NB Ventura County Point Mugu	N	CA	M	6	MS	Adj-Smaller City
NB Ventura County Port Hueneme	N	CA	MS	3	S	Embedded Urban
NCBC Gulfport	N	MS	MS	2	S	Adj-Smaller City
Nellis AFB	AF	NV	ML	22	M	Adj-Lg Metro Area
NS Everett	N	WA	M	0.3	VS	Adjacent Town
NS Great Lakes	N	IL	M	3	S	Adj-Smaller City
NS Newport	N	RI	M	2	S	Adj-Smaller City
NS Norfolk	N	VA	VL	7	MS	Adj-Lg Metro Area
NS San Diego	N	CA	VL	3	S	Embedded Urban
NSA Mid-South	N	TN	M	3	S	Adjacent Town
NSA Panama City	N	FL	MS	1	S	Adj-Smaller City
NSB New London	N	CT	M	1	S	Separated, periurban
NSB Point Loma	N	CA	L	2	S	Adj-Lg Metro Area
NWS Seal Beach	N	CA	S	8	MS	Embedded Urban
NWS Yorktown	N	VA	S	20	M	Adj-Lg Metro Area
Offutt AFB	AF	NE	ML	6	MS	Adj-Smaller City
Patrick AFB	AF	FL	ML	4	S	Adj-Smaller City
Peterson AFB	AF	CO	M	2	S	Adj-Lg Metro Area
Picatinny Arsenal	A	NJ	M	10	MS	Adjacent Town
Portsmouth NS	N	ME	MS	0.5	VS	Adj-Smaller City
Rock Island Arsenal	A	IL	M	1	S	Adj-Smaller City

Installation Name	Serv -ice	ST	Pop. (Day)	Area		Siting Relative to Development
				sq. mi.	Cat.	
Seymour Johnson AFB	AF	NC	M	5	MS	Adj-Smaller City
Sheppard AFB	AF	TX	L	10	MS	Adj-Smaller City
Tinker AFB	AF	OK	L	6	MS	Adj-Lg Metro Area
Travis AFB	AF	CA	ML	9	MS	Adj-Smaller City
Tyndall AFB	AF	FL	M	15	MS	Adj-Lg Metro Area
Vance AFB	AF	OK	S	8	MS	Adj-Smaller City
Vandenberg AFB	AF	CA	MS	156	VL	Adjacent Town
Wright-Patterson AFB	AF	OH	L	13	MS	Adj-Lg Metro Area

Appendix D: Compilation of Data for On-Site Wastewater Treatment Facilities

Installation (WWTP name in parantheses when more than one plant per installation)	**Treatment Technology** (secondary or below)	**Capa-city**	**Business Model**[a]	**NPDES Permit #**
ADVANCED				
Fort Hood	Activated sludge	VS	COCO	TX0002313
Fort Meade		L	COCO	MD0021717
MCB Camp Lejeune		VL	GOGO	NC0063029
MCB Quantico (Camp Upshur)		VS	GOGO	VA0028371
NAS Jacksonville		ML	GOGO	FL0000957
Fort Carson	Oxidation ditch	L	GOGO	CO0021181
Fort Riley (auxillary)		M	GOGO	
MCB Camp Pendleton (Northern Regional Tertiary)	Sequencing batch reactor	L	GOGO	CA0109347
Fort Polk (South Fort)	Trickling filter	L	COCO	LA0032221
Fort Polk (North Fort)		VL	COCO	LA0032239
Eglin AFB (Duke Field)	Secondary processes prior to advanced not known	S	GOGO	
Fort Huachuca		VL	COCO	AZU000165
MCAS Cherry Point		L	GOGO	
MCB Camp Pendleton (Southern Regional Tertiary)		VL	GOGO	CA0109347
Redstone Arsenal		VL	COCO	AL0062863
SECONDARY				
Anniston Army Depot	Activated sludge	M	GOGO	
Creech AFB		S	GOGO	
Eglin AFB (Auxilliary Field #6)		VS	GOGO	
Fort A.P. Hill		M	COCO	VA0032034
Fort Rucker		ML	COCO	AL0076821
JB San Antonio - Camp Bullis		M	GOGO	
MacDill AFB		ML	GOGO	
MCAGCC 29 Palms		ML	GOGO	
NAS Corpus Christi		ML	GOGO	
NAS Fallon		M	GOGO	NV0110001
NAS Key West		MS	GOGO	FLR05B002
NAS Patuxent R. Webster Field Annex		VS	GOGO	MD0020095
Shaw AFB		ML	GOGO	SC0024970

[a]Alternative business models are shaded in yellow.

Installation (WWTP name in parantheses when more than one plant per installation)	**Treatment Technology** (secondary or below)	**Capa-city**	**Business Model**	**NPDES Permit #**
Blue Grass Army Depot	Oxidation ditch	MS	GOGO	KD0020699
Fort Irwin		VS	GOGO	
Fort Riley (main)		ML	GOGO	
NSF Indian Head		MS	GOGO	WA0021997
Dugway Proving Grnd	Oxidation Pond	MS	GOGO	UGW450007
Grand Forks AFB		M	GOGO	ND0020621
Laughlin AFB		M	GOGO	
MCLB Barstow (main)		ML	GOGO	
NAWS China Lake		ML	GOGO	
Picatinny Arsenal		M	GOCO	
Pine Bluff Arsenal (North)		M	GOGO	AR0001678
Pine Bluff Arsenal (South)		S	GOGO	AR0001678
NSA Crane	Rotating biological contactor	ML	GOGO	IN0021539
MCB Quantico (Mainside)	Sand filters	ML	GOGO	VA00028363
Naval Magazine Indian I.		ML	GOGO	WA0021997
Cannon AFB	Sequencing batch reactor	ML	GOCO	NM0030236
Mountain Home AFB		M	GOCO	ID0027642
NAS Whidbey Island - Ault Field		M	GOGO	WA0003468
Aberdeen Proving Ground	Trickling filter	ML	GOGO	MD0021229
Arnold AFB		M	GOGO	
Beale AFB		L	GOGO	
Defense Distr Depot San Joaquin - Reg West Tracy		VS	GOGO	
Defense Distr Depot San Joaquin - West Sharpe		MS	GOGO	
Ellsworth AFB		ML	GOCO	SD0000281
Fort Benning		L	POPO	GA0000973
Fort Campbell		L	COCO	KYR10F698; KYG200050
Fort Detrick		ML	COCO	MD0020877
Fort Leonard Wood		L	GOGO	MO0029742
Fort McCoy		ML	GOGO	WI0022420
Iowa Army Ammunition Plant (Main)		M	GOGO	
Iowa Army Ammunition Plant (Line 3A)		ML	GOGO	
JB Lewis-McChord		VL	GOGO	WA0021954
McAlester Army Ammunition Plant		M	GOGO	OK0000523
MCAS Beaufort		M	GOCO	SC0000825
MCRD Parris Island		ML	GOGO	
Moody AFB		M	GOGO	
Scott AFB		ML	GOGO	IL0026859
Tobyhanna Army Depot		M	GOGO	PA0010987
White Sands Missile Range		MS	GOGO	
Whiteman AFB		ML	GOGO	MO0029378
Holloman AFB	unknown	L	GOGO	NM0029971

Installation (WWTP name in parantheses when more than one plant per installation)	**Treatment Technology** (secondary or below)	**Capa-city**	**Business Model**	**NPDES Permit #**
PRIMARY				
Edwards AFB	Stabilization Pond (primary)	L	GOGO	
Eglin AFB (Main base)		L	GOGO	
Eglin AFB (Hurlburt Field)		M	GOGO	
Minot AFB		L	GOGO	ND0020486
NAF El Centro		S	GOGO	CA0104906
NAS Lemoore		ML	GOGO	
Schriever AFB		ML	GOGO	
Fort Stewart	unknown primary treatment	VS	POPO	GA0004308
Fort Stewart - Hunter Army Airfield		ML	GOGO	GA0027588
McAlester Army Ammunition Plant - Camp Stanley Storage Activity		S	GOGO	
NS Mayport		ML	GOGO	
Red River Army Depot		S	COCO	TX0126098
Savanna Army Depot		S	GOPO	
SEPTIC TANKS				
NB Kitsap, Bangor	Septic tank, drain field	ML	GOGO	
PRE-TREATMENT SETTLING PONDS				
Hawthorne Army Depot	Septic Lagoon/ Settlement Pond	VS	GOGO	
Tooele Army Depot		VL	GOGO	
Yuma Proving Ground		S	GOGO	
UNKNOWN TREATMENT				
Fort Sill	Unknown	L	COCO	OK0030295
JB Charleston		L	GOGO	
JB McGuire-Dix-Lakehurst - Fort Dix		VL	GOCO	
JB McGuire-Dix-Lakehurst - McGuire		L	GOGO	
MCLB Albany		ML	GOGO	
MCLB Barstow (Yermo Area)		ML	GOGO	VA00028363
NAS Kingsville		MS	GOGO	
NB Ventura County San Nicolas I.		VS	GOGO	CAG990004
NSA Northwest Annex, Chesapeake		S	GOGO	
NSB Kings Bay (Waterfront)		MS	GOGO	GA0027707
NSB Kings Bay (Upper Base)		ML	GOGO	
NSF Dahlgren		M	GOGO	VA0026514
NWS Earle		MS	GOGO	NJ0023540
Robins AFB (MTC)		MS	GOGO	
Robins AFB (AFRC)		L	GOGO	